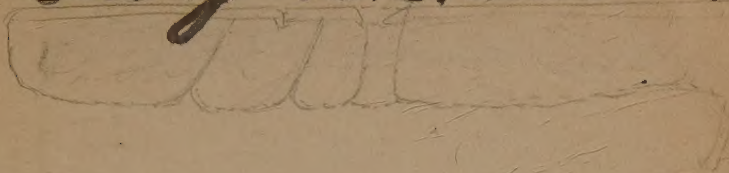
ELEMENTS OF BOTANY

BERGEN

George W. Huschart.



A BRAZILIAN FOREST INTERIOR, WITH AIR-PLANTS AND LIANAS.

ELEMENTS OF BOTANY

BY

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PREFACE.

The present text-book is, for the most part, an expansion of the manuscript notes which have for some years formed the basis of the botany-teaching in the Boston English High School. These notes were drawn up by Mr. Samuel F. Tower and the author, for the purpose of establishing what seemed to them a suitable half-year course in botany for pupils of the entering class in that school.

It will be found that this book differs from most American text-books designed for use in secondary schools, in endeavoring to combine in one volume the simplest possible directions for laboratory work with an outline of vegetable anatomy and physiology, and a brief statement of the principles of botanical classification. An account of the functions of the tissues or organs described usually follows as closely as may be the account of the parts in question. The attempt is made to discuss plants dynamically rather than statically, to view them as contestants in the struggle for existence, and to consider some of the conditions of success and failure in the vegetable world. While the determination of species by means of an artifical key is illustrated, preparation for this process is by no means the main object or even a principal end which the author has had in view. The tendency of botany-teaching seems to be more and more away from the old ideal of enabling one's pupils to run down a species as expeditiously as possible, and teaching them how to preserve a properly ticketed memento of the chase.

The illustrations drawn from nature, or redrawn expressly for this book, are mostly by Orville P. Williams or Francis M. West, recent graduates of the English High School. The woodcut of *Monotropa* is from a photograph kindly loaned for the purpose by its maker, Rev. R. S. Morison. Large numbers of illustrations have been reproduced from the following works, which are named in about the order of the extent to which they have been drawn upon:

Le Maout and Decaisne's *Traité Général de Botanique.*
Thomé's *Structural and Physiological Botany.*
Tschirch's *Angewandte Pflanzenanatomie.*
Strasburger, Noll, Schenk, and Schimper's *Lehrbuch der Botanik.*
Kerner's *Pflanzenleben.*
Figuier's *Vegetable World.*
Behrens's *Text-book of General Botany.*
Sachs's *Text-book of Botany.*

The author is to a less extent indebted for cuts to the works of Brown, Carpenter, Darwin, Lindley, Lubbock, Potonie, Strasburger, Hartig, Host, Kny, Detmer, Martius, Baillon, and others.

For most of the subject-matter of this book — though not for the order and mode of treatment — the writer is of course indebted to a multitude of sources, only a very few of which are indicated in the subjoined bibliography. Personal assistance has been freely rendered him by Prof. George L. Goodale, Dr. Benjamin L. Robinson, Curator of the Gray Herbarium, and Mr. A. B. Seymour of the Cryptogamic Herbarium of Harvard University. Prof. George J. Pierce of Indiana State University has given valuable aid in regard to some physiological questions. Prof. William F. Ganong of Smith College has done so much for the book that if it should prove useful its value will be largely due to his suggestive criticisms. Thanks are due for the careful proof-reading of

Prof. George G. Groff of Bucknell University, Lewisburg, Pa., Miss Anna A. Schryver of the Michigan State Normal School, Ypsilanti, Mr. Hermann von Schrenk of the St. Louis Manual Training School, and Mr. Marcus L. Glazer of the St. Cloud, Minn., High School.

Part II is furnished in four different forms. That which is intended for use in the Northeastern States is a Key and Flora compiled by the author of Part I.

That which accompanies the Pacific Coast Edition has been prepared by Miss Alice Eastwood of the California Academy of Sciences.

That which accompanies the Rocky Mountain and Salt Lake Basin Edition is also by Miss Eastwood.

That of the Southern United States Edition is by Prof. S. M. Tracy, late Director and Botanist of the Mississippi Agricultural Experiment Station, and former Professor of Botany in the University of Missouri.

Each of these four floras includes all the plants of the region treated which are best adapted, by their time of blooming, commonness of occurrence, and simplicity of structure, for study in secondary schools. Pupils can obtain from the especial flora of their region ample drill in the determination or analysis of plants, even in schools where that is made an important feature of the botany teaching.

CONTENTS.

Part I.

ELEMENTS OF BOTANY.

INTRODUCTORY.

"Botany is the science which endeavors to answer every reasonable question about plants." [1]

The plant is a living being, provided generally with many parts, called *organs*, which it uses for taking in nourishment, for breathing, for protection against its enemies, and for reproducing itself and so keeping up the numbers of its own kind. The study of the individual plant therefore embraces a variety of topics, and the examination of its relation to others introduces many more subjects.

Morphology, or the science of form, structure, and so on, deals with the plant without much regard to its character as a living thing. Under this head are studied the forms of plants and the various shapes or disguises which the same sort of organ may take in different kinds of plants, their gross structure, their microscopical structure, their classification, and the successive stages in the history of the germs from which all but a few of the very simplest plants are formed.

Geographical Distribution, or botanical geography, discusses the range of the various kinds of plants over the earth's surface. Another subdivision of botany, usually studied along with geology, describes the history of plant life on the earth from the appearance of the first plants until the present time.

[1] Professor George L. Goodale.

Vegetable Physiology treats of the plant in action, how it lives, breathes, feeds, grows, and produces others like itself.

Vegetable Ecology treats of the relations of the plant to the conditions under which it lives. Under this division of the science are studied the effects of soil, climate, and friendly or hostile animals and plants on the external form, the internal structure and the habits of plants.

Many of the topics suggested in this outline cannot well be studied in the high school. There is not usually time to take up botanical geography or to do much more than mention the important subject of *Economic Botany*, the study of the uses of plants to man. It ought, however, to be possible for the student to learn in his high school course a good deal about the simpler parts of morphology and of vegetable physiology. One does not become a botanist — not even much of an amateur in the subject — by reading books about botany. It is necessary to study plants themselves, to take them to pieces and make out the connection of their parts, to examine with the microscope small portions of the exterior surface and thin slices of all the variously built materials or *tissues* of which the plant consists. All this can be done with living specimens or with those taken from dead parts of plants that have been preserved in any suitable way, as by drying or by placing in alcohol or other fluids which prevent decay. Living plants must be studied in order to ascertain what kinds of food they take, what kinds of waste substances they excrete, how and where their growth takes place and what circumstances favor it, how they move, and indeed to get as complete an idea as possible of what has been called the behavior of plants.

Since the most familiar and most interesting plants spring from seeds, the beginner in botany can hardly do better than to examine at the outset the structure of a few familiar seeds,

then sprout them and watch the growth of the seedlings which spring from them. Afterwards he may study in a few typical examples the organs, structure, and functions of flowering plants, trace their life-history, and so, step by step, follow the process by which a new crop of seeds at last results from the growth and development of such a seed as that with which he began.

Meantime it will throw light on the mode of growth of flowering plants to compare them with a few very simple flowerless plants.

After the whole round of vegetable life has been outlined from seed to seed, the student may learn a little about the never-ceasing struggle against unfavorable climates, poor soils, and the direct attacks of living enemies, — in short, the many kinds of adverse influences, such as all plants must meet and overcome in order to maintain their footing on the earth.

Finally, some idea may be gained of the relationships of plants to each other, or *Systematic Botany*.

CHAPTER I.

The Seed and its Germination.

1. *Germination of Squash-Seed.*— Soak some squash-seeds in tepid water for twelve hours or more. Plant these about an inch deep in damp sand or pine sawdust in a wooden box which has had holes enough bored through the bottom so that it will not hold water. Put the box in a warm place (not at any time over 70° or 80° Fahrenheit), and cover it loosely with a board or a pane of glass. Keep the sand or sawdust moist, but not wet, and the seeds will germinate. As soon as any of the seeds, on being dug up, are found to have burst open, sketch one in this condition, noting the manner in which the outer seed-coat is split, and continue to make sketches at intervals of two days, until at least eight stages in the growth of the plantlet have been noted.[1]

Observe particularly how the sand is pushed aside by the rise of the young seedlings, and make one sketch to show what part of the plant first appears above the surface. Suggest some reason for the manner in which the sand is penetrated by the rising stem.

The student need not feel that he is expected to make finished drawings to record what he sees, but some kind of sketch, if only the merest outline, is indispensable. Practice and the study of the illustrations hereafter given will soon give some facility even to those who have had little or no instruction in drawing. Consult here Figs. 7 and 58.

2. *Examination of the Squash-Seed.*— Make a sketch of the dry seed, natural size. Note the little scar at the pointed end of the seed where the latter was attached to its place of growth in the squash. Label this *hilum*.

Describe the color and texture of the outer coating of the seed. With a scalpel or a very sharp knife cut across near the middle a seed that has been soaked in water for 24 hours. Squeeze one of the portions, held edgewise between the thumb and finger, in such a way as to separate slightly the halves into which the contents of the seed is naturally divided. Examine with the magnifying glass the section thus treated,

[1] The class is not to wait for the completion of this work (which may, if desirable, be done by each pupil at home), but is to proceed at once with the examination of the squash-seed and of other seeds, as directed in the following sections, and to set some beans to sprouting, so that they may be studied along with the germinating squashes.

make a sketch of it and label the shell or covering of the seed and the kernel within this.

Taking another soaked seed, chip away the white outer shell, called the *testa*, and observe the thin, greenish inner skin, the *tegmen*, with which the kernel of the seed is closely covered.

Strip this off and sketch the uncovered kernel, or *embryo*. Note that at one end it tapers to a point. This pointed portion, known as the *caulicle*, will develop after the seed sprouts into the stem of the plantlet, like that shown at *hc* in Fig. 1.

Split the halves of the kernel entirely apart from each other, noticing that they are only attached for a very little way next to the caulicle, and observe the thickness of the halves and the slight unevenness of the inner surfaces. These halves are called seed-leaves or *cotyledons*.

Have ready some seeds which have been soaked for 24 hours and then left in a loosely covered jar on damp blotting-paper at a temperature of 70° or over until they have begun to sprout.

Split one of these seeds apart, separating the cotyledons, and observe, at the junction of these, two very slender pointed objects, the rudimentary leaves of the *plumule* or first bud.

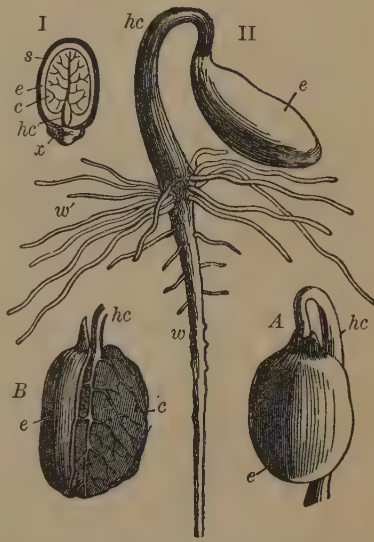


Fig. 1. — The Castor Bean and its Germination.
I, longitudinal section of the ripe seed; II, germinating seed; *hc*, caulicle; *c*, cotyledon; *e*, nourishment stored around the cotyledons; *s*, testa; *x*, thickened knot at end of seed; *w*, primary root; *w′*, secondary roots.

3. *Examination of the Bean.* — Study the seed, both dry and after 12 hours' soaking, in the same general way in which the squash-seed has just been examined.[1]

[1] The larger the variety of bean chosen, the easier it will be to see and sketch the several parts. The large red kidney bean or the horticultural bean will do well for this examination.

Notice the presence of a distinct plumule, consisting of a pair of rudimentary leaves between the cotyledons, just where they are joined to the top of the caulicle.

Make a sketch of these leaves as they lie in place on one of the cotyledons, after the bean has been split open.

Note the cavity in each cotyledon caused by the pressure of the plumule. Place that cotyledon from which the sketch was made on the stage of the compound microscope under the lowest-power objective which the microscope has (say 2-inch), with light thrown on the object from above, and sketch the plumule as thus shown.[1]

4. *Examination of the Pea.* — There are no very important points of difference between the bean and pea, so far as the structure of the seed is concerned, but the student should rapidly dissect a few soaked peas to get an idea of the appearance of the parts, since he is to study the germination of peas in some detail.

Make only one sketch, that of the caulicle as seen in position after the removal of the seed-coats.[2]

5. *Germination of the Bean and the Pea.* — Soak some beans as directed in § 3, plant them, and sketch as there directed.

Follow the same directions with some peas.[3]

6. *Germination of the Horse-Chestnut.* — Plant some seeds of the horse-chestnut or the buckeye, study their mode of germination and make out the nature and peculiar modifications of the parts.

Consult Gray's *Botanical Text-Book*, vol. I, pp. 19, 20.

7. *Conditions Requisite for Germination.* — When we try to enumerate the external conditions which can affect germination, we find that the principal ones are light, heat, moisture, and presence of air. A few simple experiments will show what influence these conditions exert.

8. ***Experiment 1.***[4] (a) *Does Light assist Germination?* (b) *Does Light retard Germination?* — Put a piece of blotting-paper in the bottom

[1] The teacher should at this point give a short illustrated talk to explain in a general way the construction and use of the compound microscope. See Appendix A.

[2] The teacher will find excellent sketches of most of the germinating seeds described in the present chapter in Miss Newell's *Outlines of Lessons in Botany*, Part I, and in Gray's *Lessons in Botany*.

[3] The pupil may economize space by planting the new seeds in boxes from which part of the earlier-planted seeds have been dug up for use in sketching, etc.

[4] This may readily be made a home experiment.

of a tumbler, and add just water enough thoroughly to soak the paper. Pour out any excess. Place on the paper a few seeds (peas, barley, wheat, oats) that have been soaked for 24 hours; cover to prevent evaporation and put the tumbler in a light place.

Put the same number of other seeds of the same sort in a cup or box which will not admit light.

Add a few drops of water from time to time, if the seeds or paper seem to be drying. Place the cup and tumbler side by side, so that they will have the same temperature, and watch for results.

Tabulate your results something like this:

No. of seeds sprouted in	24 hrs.	48 hrs.	72 hrs.	96 hrs.
In dark,	——	——	——	——
In light,	——	——	——	——

N. B. — Take special pains to have the conditions of moisture and heat the same in the cup and in the tumbler.

9. ***Experiment 2.*** *Relation of Temperature to Germination.* — Arrange several vessels as in Exp. 1. Put in each vessel the same number of soaked peas.[1] Stand the vessels with their contents in places where they will be exposed to different, but fairly constant, temperatures and observe the several temperatures carefully with a thermometer. The following series is merely suggested, — other values may be found more convenient. Note the rate of germination in each place and record in tabular form as follows:

No. of seeds sprouted in	24 hrs.	48 hrs.	72 hrs.	96 hrs.	etc.
At 32 degrees,	——	——	——	——	——
At 50 degrees,	——	——	——	——	——
At 70 degrees,	——	——	——	——	——
At 90 degrees,[2]	——	——	——	——	——

10. ***Experiment 3.***[3] *Relation of Water to Germination.* — Arrange seeds in several vessels as follows:

In the first put blotting-paper that is barely moistened: on this put some dry seeds.

[1] If peas are used one year, Indian corn another year, squash-seeds another, and so on, a series of data will be obtained which may be quoted to the class after the experiment as above given has been completed.

[2] Here and elsewhere throughout the book temperatures are expressed in Fahrenheit degrees, since with us, unfortunately, the Centigrade scale is not the familiar one, outside of physical and chemical laboratories.

[3] May be a home experiment.

In the second put blotting-paper that has been barely moistened; on this put seeds that have been soaked for 24 hours.

In the third put water enough thoroughly to soak the paper: use soaked seeds.

In the fourth put water enough to half cover the seeds.

Place the vessels where they will have same temperature and note the time of germination.

Tabulate your results as in the previous experiments.

11. *Experiment 4.**[1] *Will Seeds germinate without Air?*— Place some soaked seeds on blotting-paper in the bottom of a bottle; close tightly with a perforated rubber stopper through which has been passed a long glass tube bent once at right angles as shown in Fig. 2.

FIG. 2.—Soaked Peas in Stoppered Bottle, ready for Exhaustion of Air.

Exhaust the air from the bottle by attaching the tube to an air-pump or an aspirator, and after considerable pumping and while the exhaustion is going on, seal the whole air-tight by heating the tube near the bend with a Bunsen burner or alcohol lamp flame until it can be drawn out to a thread.

The stopper will be more certain to prove air-tight if it has been well moistened with glycerine or vaseline before being inserted in the bottle.

Place other seeds of the same kind in another bottle and stopper tightly.

Place other seeds of the same kind in a third bottle; stopper loosely.

Place the three bottles side by side, so that they will have the same conditions of light and heat. Watch for results, and tabulate as in previous experiments.

Most seeds will not germinate under water, but those of the sunflower will do so, and therefore Exp. 4 may be varied in the following manner:

[1] Experiments marked thus * are to be performed by the teacher in the laboratory or class-room.

Remove the shells carefully from a considerable number of sunflower seeds.[1] Try to germinate one lot of these in water which has been boiled, to remove the air, and then cooled and poured into a bottle which it fills up to the (tightly fitting) rubber stopper. In this bottle then there will be only seeds and water, no air-space. Try to germinate another lot of seeds in a bottle half filled with ordinary water.

12. *Germination involves Chemical Changes.* — If a thermometer is inserted into a jar of sprouting seeds, for instance peas, in a room at the ordinary temperature, the peas will be found to be warmer than the surrounding air. This rise of temperature is at least partly due to the absorption from the air of that substance in it which supports the life of animals and maintains the burning of fires, namely *oxygen.*

The union of oxygen with substances with which it can combine, that is with those which will burn, is called *oxidation.* This kind of chemical change is universal in plants and animals while they are in an active condition, and the energy which they manifest in their growth and movements is as directly the result of the oxidation going on inside them as the energy of a steam-engine is the result of the burning of coal or other fuel under its boiler. In the sprouting seed much of the energy produced by the action of oxygen upon oxidizable portions of its contents is expended in producing growth, but some of this energy is wasted by being transformed into heat which escapes into the surrounding soil. It is this escaping heat which is detected by a thermometer thrust into a quantity of germinating seeds.

13. ***Experiment 5.**** *Effect of Germinating Seeds upon the Surrounding Air.* — When Exp. 4 has been finished, insert into the air above the peas in the second bottle a lighted pine splinter, and note the effect upon its flame.

Besides the proofs of chemical changes in germinating seeds just described, there are other kinds of evidence to the same effect.

[1] These are really fruits, but the distinction is not an important one at this point.

Malt, which is merely sprouted barley with its germination permanently stopped at the desired point by the application of heat, tastes much sweeter than the unsprouted grain, and can be shown by chemical tests to have suffered a variety of changes.

Germinating kernels of corn undergo great alterations in their structure (see Fig. 12).

14. *The Embryo and its Development.* — The miniature plant, as it exists ready-formed in the seed, is called the *embryo*. In the seeds so far examined the entire contents of the seed-coats consist of the embryo, but this is not the case with the great majority of seeds.

As soon as the young plants of squash, bean, and pea have reached a height of three or four inches above the ground it is easy to recognize important differences in the way in which they set out in life.

The cotyledons of the squash increase greatly in surface, acquire a green color and a generally leaf-like appearance, and, in fact, do the work of ordinary leaves. In such a case as this the appropriateness of the name seed-leaf is evident enough, — one recognizes at sight the fact that the cotyledons are actually the plant's first leaves. In the bean the leaf-like nature of the cotyledons is not so clear. They rise out of the ground like the squash cotyledons, but then gradually shrivel away, though they may first turn green and somewhat leaf-like for a time.

In the pea (as in the acorn, the horse-chestnut, and many other seeds) we have quite another plan, the underground type of germination. Here the thick cotyledons no longer rise above ground at all, because they are so gorged with nourishment that they could never become leaves; but the young stem pushes rapidly up from the surface of the soil.

The development of the plumule seems to depend somewhat on that of the cotyledons. The squash-seed has cotyledons

which are not too thick to become useful leaves, and so the plant is in no special haste to get ready any other leaves. The plumule, therefore, cannot be found with the magnifying glass in the unsprouted seed, and is almost microscopic in size at the time when the caulicle begins to show outside of the seed-coats.

In the bean and pea, on the other hand, since the cotyledons cannot serve as leaves, the later leaves must be pushed forward rapidly. In the bean the first pair are already well formed in the seed. In the pea they cannot be clearly made out, since the young plant forms several scales on its stem before it produces any full-sized leaves, and the embryo contains only caulicle, cotyledons, and a sort of knobbed plumule, well developed in point of size, representing the lower scaly part of the stem.

CHAPTER II.

The Parts of the Seedling; — its Development.

15. *Root, Stem, and Leaf.* — By the time the seedling is well out of ground it, in most cases, possesses the three kinds of *vegetative organs*, or parts essential to growth, of ordinary flowering plants, the root, stem, and leaf. All of these organs may multiply and increase in size as the plant grows older, and their mature structure will be studied in later chapters, but some facts concerning them can best be learned by watching their growth from the outset.

16. *The Young Root.* — Roots growing in sand or ordinary soil cling to its particles so tenaciously that they cannot easily be studied, and those grown in water have not quite the same form as soil roots. Roots grown in damp air are best adapted for careful study.

Experiment 6. *In what Portions of the Root does its Increase in Length take Place?* — Sprout some peas on moist blotting-paper in a loosely covered tumbler. When the roots are one and a half inches or more long, mark them along the whole length with little dots made with a very small camel's-hair brush or a bristle dipped in water-proof India ink.

Transfer the plants to moist blotting-paper under a bell glass or a battery jar and examine the roots at the end of twenty-four hours to see along what portions their length has increased; continue observations on them for several days.

17. *Root-Hairs.* — Barley, oats, wheat, or red clover seed soaked and then sprouted on moist blotting-paper afford convenient material for studying *root-hairs.* The seeds may be kept covered with a watch-glass or a clock-glass while sprouting. A few of the red clover seeds should also be sprouted in a deep cell on a microscope-slide. Examine those parts of the root which have these appendages, first with the magnify-

ing glass, then as opaque objects in a cell under a low power of the miscroscope; finally cut off a very small portion of the root with its hairs and examine in water with a power of 150 to 200 diameters.[1]

Make several sketches of the root-hairs and compare with Figs. 5 and 19. Notice that they do not cover all portions

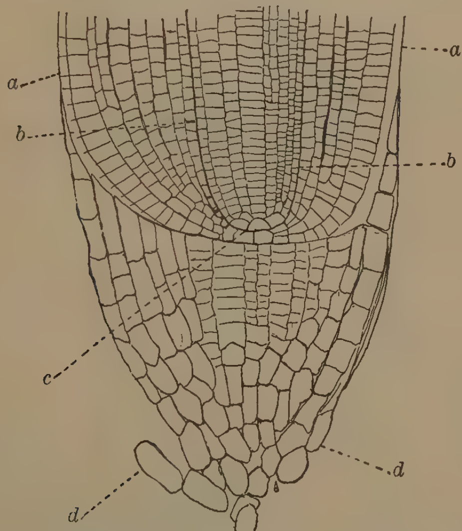


FIG. 3.—Lengthwise Section through Tip of a Root of Barley. (Much magnified.) *a*, thick outer wall of epidermis; *b* (portion bounded by the heavy line), the central cylinder of the root; *c*, the growing-point, from which the root-cap is produced (in this and similar plants) and from which growth in length proceeds; *d*, loose cells of the root-cap.

of the rootlets. Where are they most abundant? Observe that each hair is a slender closed tube, with very thin walls made of the tough material called *cellulose*.

The root-hairs in plants growing under ordinary conditions

[1] Great care is needed to prevent the root-hairs from becoming distorted by pressure, and they shrivel up in dry air almost at once.

are surrounded by the moist soil and wrap themselves around microscopical particles of earth. Thus they are able rapidly to absorb through their thin walls the soil-water, with whatever mineral substances it has dissolved in it.

18. *The Root-Cap.*—The tips of young roots and rootlets,

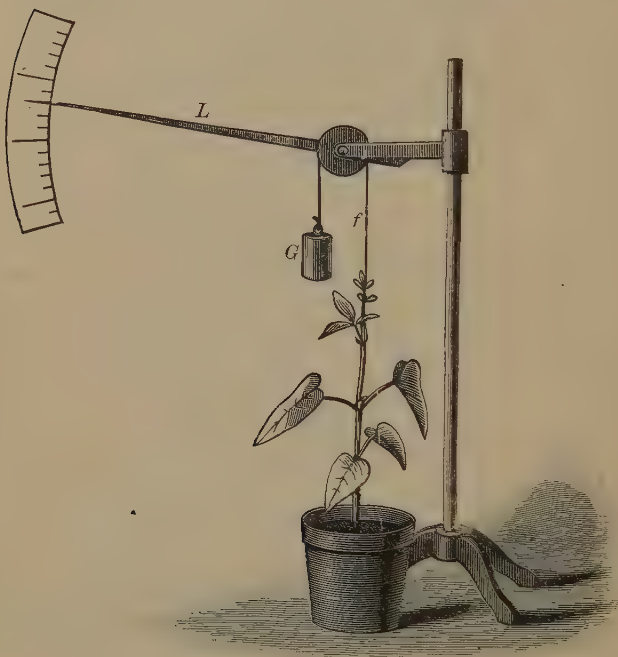


FIG. 4.—Apparatus for Measurement of Growth.

as they bore their way through the soil, are protected from injury by a coating of loose cells, called the *root-cap*, shown at *d* in Fig. 3. It will be seen from this figure that no root-hairs proceed from the root-cap, and indeed there is very little absorption of water going on in this place. In the so-

called water-hyacinth[1] that which occupies the place of an ordinary root-cap is a long sheath, which may be pulled off entire; its large size is possibly due to the fact that it is not worn away by friction against the soil.

19. *The Young Stem.*—The caulicle, or portion of the stem which lies below the cotyledons, is the earliest-formed portion of the stem. Sometimes this lengthens but little; often, however, as the student knows from his own observations, the caulicle lengthens enough to raise the cotyledons well above ground, as in Fig. 5.

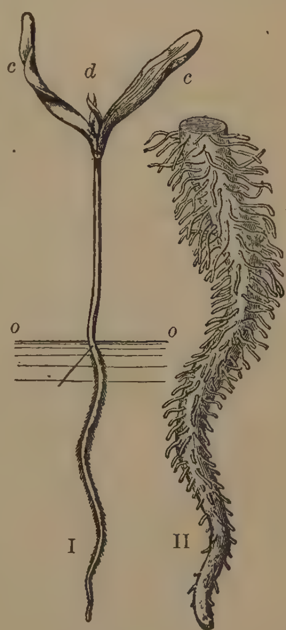


FIG. 5.—I, a seedling maple, natural size; *c*, cotyledons; *d*, plumule; *o*, level of the ground; II, part of root of the same, magnified six times, showing root-hairs.

The later portions of the stem are considered to be divided into successive *nodes*, places at which a leaf (or a scale which represents a leaf) appears, and *internodes*, portions between the leaves.

The student should watch the growth of a seedling bean or pea and ascertain by actual measurements whether the internodes lengthen after they have once been formed, and if so, for how long a time the increase continues.

The rate of growth may readily be measured by means of a simple piece of apparatus, shown in Fig. 4. This consists of a pointer *L* supported by an upright stand, moving over a graduated arc, and with a grooved

[1] A plant somewhat common in greenhouses, allied to the ordinary pickerel weed of the streams and ponds of New England.

pulley attached to its axis. Over this pulley a cord f passes. One end of the cord is fastened to the tip of the stem of the plant of which the growth is to be measured and the other end has a weight G attached to it. As the plant grows the pointer L descends on the scale. The actual rate of growth is obtained by multiplying the distance which the pointer travels over the arc by the fraction which expresses the ratio of the half-diameter of the pulley to the length of L from arc to pivot.

Contrast the mode of growth of the root and the stem and try to give a reason for that of the root.

20. *The First Leaves.*—The cotyledons are, as already explained, the first leaves which the seedling possesses,—even if a plumule is found well developed in the seed, it was formed after the cotyledons. In those plants which have so much nourishment stored in the cotyledons as to render these unfit ever to become useful leaves, there is little or nothing in the color, shape, or general appearance of the cotyledon to make one think it really a leaf, and it is only by studying many cases that the botanist is entitled to class all cotyledons as leaves in their nature, even if they are quite unable to do the work of leaves. The study of the various forms which the parts or organs of a plant may assume is called *morphology;* it traces the relationship of parts which are really akin to each other, though dissimilar in appearance and often in function. In seeds which have *endosperm*, or nourishment stored outside of the embryo, the cotyledons usually become green and leaf-like, as they do, for example, in the four-o'-clock and the morning-glory, but in the seeds of the grains (which contain endosperm) a large portion of the single cotyledon remains throughout as a thickish mass buried in the seed. In a few cases, as in the pea, there are scales instead of true leaves formed on the first nodes above the cotyledons, and it is only at about the third node above that leaves of the ordinary kind appear. In the bean and some other plants which in general bear one leaf at a node along the stem, there is a pair produced at the first node above

the cotyledons, and the leaves of this pair differ in shape from those which arise from the succeeding portions of the stem.

21. *Classification of Plants by the Number of their Cotyledons.* — In the pine family the germinating seed often displays more than two cotyledons, as shown in Fig. 6; in the majority of common flowering plants the seed contains two cotyledons, while in the lilies, the rushes, the sedges, the grasses, and some other plants there is but one cotyledon. Upon these facts is based the division of most flowering plants into two great groups: the *dicotyledonous plants*, which have two seed-leaves, and the *monocotyledonous plants*, which have one seed-leaf. Other important differences constantly accompany the difference in number of cotyledons, as will be seen later.

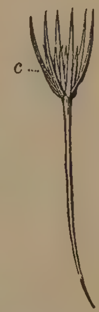


FIG. 6.—Germinating Pine. c, cotyledons.

CHAPTER III.

Storage of Nourishment in the Seed.

22. *Nourishment in the Embryo.* — Squash-seeds are not much used for human food, though both these and melon-seeds are occasionally eaten in parts of Europe, but beans and peas are important articles of food. Whether the material accumulated in the cotyledons is an aid to the growth of the young plant may be learned from a simple experiment.

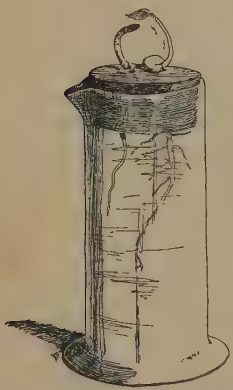


FIG. 7.—Germinating Peas, growing in Water, one deprived of its Cotyledons.

23. ***Experiment 7.**** *Are the Cotyledons of a Pea of any Use to the Seedling?*[1] — Sprout several peas on blotting-paper. When the plumules appear, carefully cut away the cotyledons from some of the seeds. Place on a perforated cork, as shown in Fig. 7, one or two seedlings from which the cotyledons have been cut, and as many which have not been mutilated, and allow the caulicles to extend into the water. Let them grow for some days, or even weeks, and note results.

24. ***Experiment 8.***[2] *Does the Amount of Material in the Seed have anything to do with the Rate of Growth of the Seedling?* — Germinate ten or more clover-seeds, and about the same number of peas, on moist blotting-paper under a bell jar. After they are well sprouted, transfer both kinds of seeds to fine cotton netting, stretched across wide-mouthed jars nearly full of water. The roots should dip into the water, but the seeds must not do so. Allow the plants to grow until the peas are from 4 to 6 inches high.

Some of the growth in each case depends on material

[1] The pea is used in a large number of the experiments here given, because it germinates at a comparatively low temperature, and the young seedlings are very hardy and thrive readily in the schoolroom.

[2] May be a home experiment.

gathered from the air and water, but most of it, during the very early life of the plant, is due to the reserve material stored in the seed.

Any one who has watched the slow growth of seedling grass plants and the very rapid growth of young corn plants can appreciate the effect of an abundant supply of food in the seed in securing a rapid start for the seedling. This particular illustration is a good one, since corn is itself a kind of grass.

25. *Storage of Nourishment outside of the Embryo.* — In very many cases the cotyledons contain little nutriment, but there is a supply of it stored in the seed beside or around them, Figs. 1 and 8.

I. II.

FIG. 8. — Seeds with Endosperm, Longitudinal Sections.

I, asparagus (magnified).
II, poppy (magnified).

26. *Examination of the Four-o'clock Seed; its Germination.* — Examine the external surface of a seed[1] of the four-o'clock, and try the hardness of the outer coat by cutting it with a knife. From seeds which have been soaked in water at least 24 hours peel off the coatings and sketch the kernel. Make a cross-section of one of the soaked seeds which has not been stripped of its coatings, and sketch the section as seen with the magnifying glass, to show the parts, especially the two cotyledons, lying in close contact and encircling the white starchy-looking *endosperm.*[2]

The name endosperm is applied to nourishment stored in parts of the seed other than the embryo. With a mounted needle pick out the little almost spherical mass of endosperm from inside the cotyledons of a seed which has been deprived of its coats, and sketch the embryo, noting how it is curved so as to inclose the endosperm almost completely.

Sketch the germinating seed and the young seedling at two or three stages of its growth to show the form and development of the cotyledons, and try to find out whether the endosperm disappears.

27. *Examination of the Kernel of Indian Corn; its Germination.* — Soak some grains of large yellow field-corn[3] for about three days.

[1] Strictly speaking a fruit.

[2] Buckwheat furnishes another excellent study in seeds with endosperm. Like that of the four-o'clock it is, strictly speaking, a fruit.

[3] The varieties with long flat kernels, raised in the Middle and Southern States under the name of "dent corn," are the best.

Sketch an unsoaked kernel, so as to show the grooved side, where the germ lies. Observe how this groove has become partially filled up in the soaked kernels.

Remove the thin tough skin from one of the latter, and notice its transparency. This skin — the bran of unsifted corn meal — does not exactly correspond to the testa and tegmen of ordinary seeds, since the kernel of corn, like all other grains (and like the seed of the four-o'clock), represents not merely the seed, but also the seed-vessel in which it was formed and grew as well as the outermost part of the flower (the *calyx*).

Cut sections of the soaked kernels, some transverse, some lengthwise and parallel to the flat surfaces, some lengthwise and at right angles to the flat surfaces. Stain with iodine solution.

Make a sketch of one section of each of the three kinds, and label the dirty white portion, of cheesy consistency, *embryo*; and the yellow portions, and those which are white and floury, *endosperm*.

Chip off the endosperm from one kernel so as to remove the embryo free from other parts.[1] Notice its form, somewhat triangular in outline, sometimes nearly the shape of a beechnut, in other specimens nearly like an almond.

Estimate what proportion of the entire bulk of the soaked kernel is embryo.

Split the embryo lengthwise so as to show the slender, somewhat conical plumule.[2]

Sprout a considerable number of kernels of corn in sand or pine sawdust, at a temperature of 70 or 80 degrees, and make several sketches to illustrate the growth of the plumule and the formation of roots; first a main root from the base of the caulicle, then others more slender from the same region, and later on still others from points higher up on the stem. The student may be able to make out what becomes of the large outer part of the embryo. This is really the single cotyledon of the corn. It does not rise above ground, but most of it remains in the buried grain, and acts as a digesting and absorbing organ through which the endosperm is transferred into the growing plant, as fast as it can be made liquid for that purpose.

[1] The embryo may be removed with great ease from kernels of rather mature green corn. After twenty minutes' boiling on the cob, pick the kernels off one by one with the point of a knife. They may be preserved indefinitely in alcohol and dissected as needed.

[2] The teacher may well consult Figs. 66, 67, 68 in Gray's *Lessons in Botany*, revised ed.

Compare the kernel of corn and its germination with the oat, Fig. 9.

28. *Experiment 9.* *Of how much Use to the Corn Seedling is the Endosperm?* — Sprout kernels of corn on blotting-paper. When they get fairly started, cut away the endosperm carefully from several of the seeds. Suspend on mosquito netting over water in the same jar two or three seedlings which have lost their endosperm, and as many which have not been mutilated. Let them grow for some weeks, and note results.

29. *Starch.* — Most common seeds contain starch. Every one knows something about the appearance of ordinary commercial starch as used in the laundry, and as sold for food in packages of corn-starch. It is not always easy, however, to recognize at sight the presence of starch as it occurs in seeds, but it may be detected by a very simple chemical test, namely, the addition of a solution of iodine.[1]

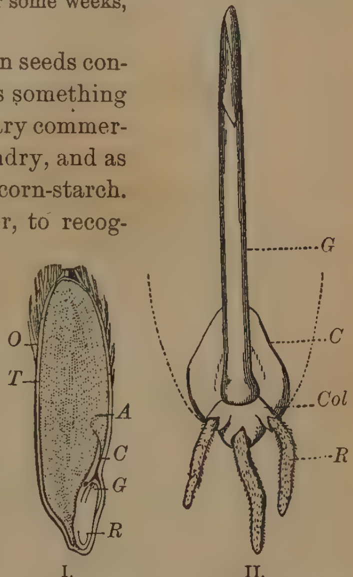


FIG. 9. — The Oat. I, Fruit, longitudinal section. *R*, caulicle; *G*, plumule; *C*, cotyledon; *A*, endosperm; *T*, testa; *O*, wall of ovary. II, Germination. *G*, plumule; *C*, cotyledon; *Col*, sheath of caulicle; *R*, root.

30. *Experiment 10.* *Test Seeds with Iodine for Starch.*[2] — Pulverize one or two seeds,[3] add two or three drops of boiling water to soften and swell the starch, and then add, drop by drop, the iodine solution. Only a little is necessary; sometimes the first drop is enough.

If starch is present, a blue color (sometimes almost black) will appear. If no color is obtained in this way, boil the pulverized seeds for a moment in a few drops of water, and try again.

[1] The tincture of iodine sold at the drug-stores will do, but the solution prepared as directed in Appendix B answers better. This may be made up in quantity, and issued to the pupil in drachm vials, to be taken home and used there, if the experimenting must be done outside of the laboratory or the schoolroom.

[2] May be a home experiment.

[3] With large seeds, like a nut, only part of one will be necessary.

Test in this manner wheat (in the shape of flour), oats (in oatmeal), barley, rice, buckwheat, flax, rye, sunflower, four-o'clock, morning-glory, beans, peanuts, Brazil-nuts, hazel-nuts, and any other seeds that you can get. Report your results in tabular form as follows:

Much Starch.	Little Starch.	No Starch.
Color, blackish or dark blue.	Color, pale blue or greenish.	Color, brown, orange, or yellowish.

31. *Microscopical Examination of Starch.* — Examine starch in water with a rather high power of the microscope (not less than 200 diameters). Pulp scraped from a potato, wheat flour, the finely powdered starch sold under the commercial name of "corn-starch" for cooking, oatmeal and buckwheat finely powdered in a mortar, will furnish five excellent examples of the shape and markings of starch-grains. Sketch all of the kinds examined, taking pains to bring out the markings.[1] Compare the sketches with Figs. 10 and 11.

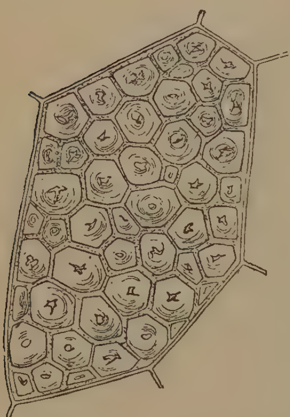


Fig. 10. — Starch-Grains stored in a Cell in a Grain of Indian Corn. (Greatly magnified.)

With a medicine-dropper or a very small pipette run in a very little iodine solution under one edge of the cover-glass, at the same time withdrawing a little water from the margin opposite by touching to it a bit of blotting-paper. Examine again and note the blue coloration of the starch-grains and the unstained or yellow appearance of other substances in the field. Cut very thin slices from beans, peas, or kernels of corn; mount in water, stain as above directed, and draw as seen under the microscope. Compare with Figs. 10 and 11.[2] Note the fact that the starch is not packed away

[1] The markings will be seen more distinctly if care is taken not to admit too much light to the object. Rotate the diaphragm beneath the stage of the microscope, or otherwise regulate the supply of light, until the opening is found which gives the best effect.

[2] The differentiation between the starch-grains, the other cell-contents, and the cell-walls will appear better in the drawings if the starch-grains are sketched with blue ink or a fine blue pencil.

in the seeds in bulk, but that it is inclosed in little chambers or *cells*.[1]

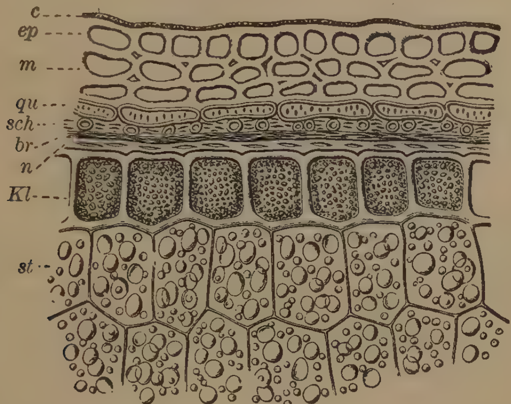


FIG. 11. — Section through Exterior Part of a Grain of Wheat.
c, cuticle or outer layer of bran; *ep*, epidermis; *m*, layer beneath epidermis; *qu*, *sch*, layers of hull next to seed-coats; *br*, *n*, seed-coats; *Kl*, layer containing proteid grains; *st*, cells of the endosperm filled with starch. (Greatly magnified.)

32. *Absorption of Starch from the Cotyledons.* — Examine with the microscope, using a medium power, soaked beans and the cotyledons from seedlings that have been growing for three or four weeks. Stain the sections with iodine solution, and notice how completely the clusters of starch-grains that filled most of the cells of the unsprouted cotyledons have disappeared from the shriveled cotyledons of the seedlings. A few grains may be left, but they have lost their sharpness of outline, and resemble somewhat the "corroded" starch-grains of Indian corn shown in Fig. 12.

FIG. 12. — Corroded Starch-Grains from Endosperm of Sprouted Indian Corn. The seedling over three inches high. The middle starch-grain of the lower row is uncorroded. (Greatly magnified.)

[1] The teacher will do well to sketch with the camera lucida a few divisions of the stage-micrometer and some cells of the seed, with contained starch-grains, on a piece of cardboard that may be passed round the class to give a precise idea of the actual and the apparent size of the objects examined.

33. *Oil.*—The presence of oil in any considerable quantity in seeds is not as general as is the presence of starch, though in many common seeds there is a good deal of it.

34. ***Experiment 11.****—To a few ounces of ground flaxseed add an equal volume of ether or benzine. Let it stand ten or fifteen minutes and then filter. Let the liquid stand in a good draught till it has lost the odor of the ether or benzine.

What have you obtained?

Of what use would it have been to the plant?

If the student wishes to do this experiment at home for himself, he should bear in mind the following:

Caution.—Never handle benzine or ether near a flame or stove.

35. *Albuminous Substances.*—Albuminous substances, or *proteids,* occur in all seeds, though often only in small quantities. They have nearly the same chemical composition as white of egg and the curd of milk among animal substances, and are essential to the plant, since the living and growing parts of all plants contain large quantities of proteid material.

Sometimes the albuminous constituents of the seed occur in more or less regular grains, Fig. 11.

But much of the proteid material of seeds is not in any form in which it can be recognized under the microscope. One test for its presence is the peculiar smell which it produces in burning. Hair, wool, feathers, leather, and lean meat all produce a well-known sickening smell when scorched or burned, and the similarity of the proteid material in such seeds as the bean and pea to these substances is shown by the fact that scorching beans and similar seeds give off the familiar smell of burnt feathers.

All proteids (and very few other substances) are turned yellow by nitric acid, and this yellow color becomes deeper or even orange when the yellowish substance is moistened with ammonia. Most proteids are turned more or less red

by the solution of nitrate of mercury known as Millon's reagent.[1]

36. *Experiment 12.*—Extract the germs from some soaked kernels of corn and bruise them, soak some wheat-germ meal for a few hours in warm water, or wash the starch out of wheat-flour dough, place in a white saucer or porcelain evaporating dish, moisten well with Millon's reagent or with nitric acid and examine after fifteen minutes.[2]

37. *Other Constituents of Seeds.*—Besides the substances above suggested, a variety of others occur in different seeds. Some of these are of use in feeding the seedling, others are of value in protecting the seed itself from being eaten by animals or in rendering it less liable to decay. In such seeds as that of the nutmeg, the essential oil which gives it its characteristic flavor probably makes it unpalatable to animals and at the same time preserves it from decay.

Date-seeds are so hard and tough that they cannot be eaten and do not readily decay. Lemon and orange seeds are too bitter to be eaten, and the seeds of the apple, cherry, peach, and plum are somewhat bitter.

The seeds of larkspur, thorn-apple,[3] croton, nux vomica, and many other kinds of plants contain active poisons.

[1] See Appendix B.

[2] It may be found interesting to test a very oily seed, such as the Brazil-nut, for starch, oil, and proteids, and then discuss the question whether any two of these three substances are apparently interchangeable, that is, whether if the plant has one it also needs the other.

[3] Datura, commonly called "Jimpson weed."

CHAPTER IV.

Roots.[1]

38. *Origin of Roots.*—The *primary root* originates from the lower end of the caulicle, as the student learned from his own observations on sprouting seeds. The branches of the primary root are called *secondary roots,* and those which occur on the stem or in other unusual places are known as *adventitious roots.* The roots which form so readily on cuttings of willow, southernwood, Tropæolum, French marigold, geranium (pelargonium), and many other plants, when placed in damp earth or water, are adventitious.

39. ***Experiment 13.***—Place in water cuttings of any kind of plant which roots readily, and sketch at intervals of two or three days the roots which are formed.

40. *Aerial Roots.*—Those roots which are formed in the air are called *aerial roots.* They serve various purposes,—in some tropical air-plants, Fig. 13, they are known to absorb moisture and other useful substances from the air and to take in water which drips from branches and trunks above them, so that these plants require no soil and grow in mid-air suspended from trees, which serve them merely as supports;[2] many such air-plants are shown in the frontispiece. In such plants as the ivy, Fig. 14, the aerial roots (which are also adventitious) hold the plant to the wall or other surface up which it climbs.

[1] To the plant the root is more important than the stem. The author has, however, treated the structure of the latter more fully than that of the root, mainly because the tissues are more varied in the stem and a moderate knowledge of the more complex anatomy of the stem will serve every purpose.

[2] If it can be conveniently managed, the class will find it highly interesting and profitable to visit any greenhouse of considerable size, in which the aerial roots of orchids and aroids may be examined.

In the Indian corn, roots are sent out from nodes at some distance above the ground and finally descend until they

FIG. 13. — Aerial Roots of an Orchid.

enter the ground. They serve both to anchor the corn-stalk so as to enable it to resist the wind and to supply additional water to the plant.[1] They produce no rootlets until they reach the ground.

[1] Specimens of the lower part of the corn-stalk, with ordinary roots and aerial roots, should be dried and kept for class study.

41. *Water Roots.* — Many plants, such as the willow, readily adapt their roots to live either in earth or in water, and some, like the little floating duckweed, regularly produce roots which are adapted to live in water only. These water roots often show large and distinct sheaths on the ends of the roots, as, for instance, in the water-hyacinth already mentioned. This plant is especially interesting for laboratory cultivation from the fact that it may readily be transferred to moderately damp soil and that the whole plant presents curious modifications when made to grow in earth instead of water.

FIG. 14. — Aerial Adventitious Roots of the Ivy.

42. *Parasitic Roots.*[1] — The dodder, the mistletoe, and a good many other *parasites* live upon nourishment which they steal from other plants. The parasitic roots or *haustoria* form the most intimate connections with the interior portions of the stem or the root, as the case may be, on which the parasite fastens itself.

In the dodder, as is shown in Fig. 15, it is most interesting to notice how admirably the seedling parasite is adapted to the conditions under which it is to live. Rooted at first in the ground, it develops a slender, leafless stem, which, leaning this way and that, no sooner comes into permanent contact with a congenial host (as the supporting plant is called) than it produces haustoria at many points, gives up further growth in its soil roots, and grows rapidly on the

[1] See Kerner and Oliver's *Natural History of Plants*, vol. I, pp. 171–213.

strength of the supplies of ready-made sap which it obtains from the host.

43. *Forms of Roots.* — The primary root is that which proceeds like a downward prolongation directly from the lower end of the caulicle. In many cases the mature root-system of the plant contains one main portion much larger than any of its branches. This is called a taproot, Fig. 16.

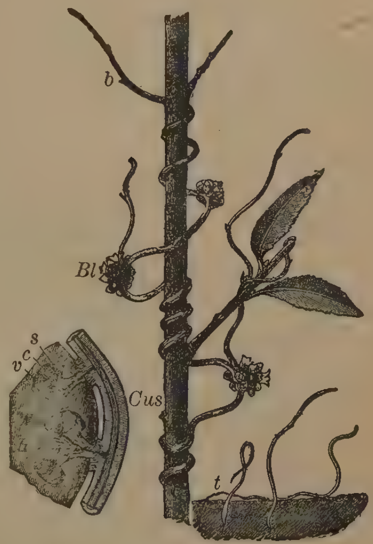


FIG. 15. — Dodder (a European species) Parasitic on the Willow.

The plant is seen encircling a willow twig, into which it sends roots from the warty inner surface of its coils.
b, scale-like leaves; *Bl*, flower-cluster.
At the left is shown the manner in which the parasite *Cus* encircles the host-plant *W*.
The parasitic roots or haustoria *H* penetrate into the parenchyma of the bark and into the fibro-vascular bundles, attaching themselves to the various kinds of tissue, *v*, *c*, *s*, which they find in these.
At the right are seedling dodder plants, the longest one growing at the tip from nourishment which it procures from the dying end next the root.

Such a root, if much thickened and fleshy, would assume the form shown in the carrot, parsnip, beet, turnip, salsify, or radish. Some plants produce *multiple primary* roots, a cluster proceeding from the lower end of the caulicle at the outset.

Roots of grasses, etc., are thread-like, and known as *fibrous roots,* Fig. 17. If such roots become thickened like those of the dahlia, Fig. 18, they are known as *fascicled roots.*

These often closely resemble tubers, but they may be distinguished from them by their mode of origin,

starting out as expansions of roots, not of underground stems like those of the potato, Fig. 35, and by the irregularity with which buds appear on their surface, if they appear at all.

44. *Structure of Roots.* — The structure of the very young root has been somewhat explained in §§ 17, 18. That of older woody roots of dicotyledons is somewhat more complicated.

FIG. 16.— A Taproot.

FIG. 17. — Fibrous Roots.

FIG. 18. — Fascicled Roots.

Cut thin transverse sections[1] of large and small roots of any hardwood tree[2] and examine them first with a low power of the microscope, as a two-inch objective, to get the general disposition of the parts, then with a higher power, as the half-inch or quarter-inch, for details. With the low power note:

(*a*) The brown layer of outer bark.

(*b*) The paler layer within this.

[1] These may be cut with a razor, flat-ground on one side and hollow-ground on the other, with a scalpel, or with a regular section-knife. The beginner will probably find much difficulty in getting good sections, but will at any rate soon obtain some which are thin enough on the edges to be fairly transparent. A section of very small area will be as good for making out detail of structure as one which extends all the way across the root. Unless a good deal of time is available for laboratory work, the sections will have to be prepared by the teacher, or they may be bought ready-cut. See Appendix C.

[2] Young suckers of cherry, apple, etc., which may be pulled up by the roots, will afford excellent material.

(c) The woody cylinder which forms the central portion of the root.

The distinction between (b) and (c) is more evident when the section has been exposed to the air for a few minutes and changed somewhat in color. It is a good plan to look with the low power first at a thick section, viewed as an opaque object, and then at a very thin one mounted in water or glycerine, and viewed as a transparent object.

Observe the cut-off ends of the *ducts*, or *vessels*, which serve as passages for air and water to travel through; these appear as holes in the

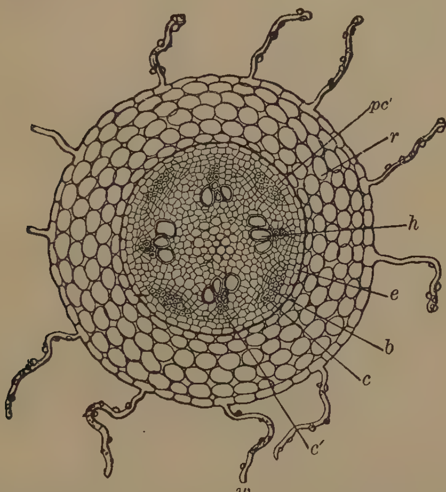


Fig. 19.—Magnified Cross-Section of a very Young Exogenous Root.
w, root-hairs with bits of sand adhering; *r*, parenchyma cells of the bark; *e*, innermost layer of the bark; *b*, bast; *h*, vessels; *c*, *c'*, cambium.

section, and are much more abundant relatively in the young than in the older and larger portions of the root. Sketch one section of each kind.

Examine with a higher power (100 to 200 diameters), and note the ends of the thick-walled wood-cells. Compare these with Fig. 19.

Notice the many thinner-walled cells composing stripes radiating away from the centre of the root. These bands are the *medullary rays*, whose mode of origin is shown in Fig. 52. Moisten some of the sections with iodine solution,[1] and note where the blue color shows the presence of starch. Split some portions of the root through the middle, cut thin

[1] If the roots are in their winter condition.

sections from the split surface and examine with the high power, with and without staining with iodine.

Notice the appearance of the wood-cells and the ducts as seen in these sections, and compare with Fig. 41.[1]

45. *Structure of Fleshy Roots.* — In some fleshy roots, such as the beet, the nature and relation of the parts is rather puzzling, since they form many layers of tissue in a single season, showing on the cross-section of the root a series of layers which look a little like the annual rings of trees, as shown in Fig. 40.

The structure of the turnip, radish, carrot, and parsnip is simpler.

Cut a parsnip across a little below the middle, and stand the cut end in red ink for 24 hours.

Then examine by slicing off successive portions from the upper end. Sketch some of the sections thus made. In what portion of the root did the colored liquid rise most readily? Cut thin cross-sections of the ink-stained parsnip at several points along its length, and examine first with the low, then with a moderately high power of the microscope. The ring of red ink marks the boundary between bark and wood. Is the main bulk of the parsnip bark or wood? Is this ring marked by the presence of any particular kind of cell? Examine a longitudinal section to help you to answer the question. Cut thin transverse sections from an ink-stained parsnip and notice how the medullary rays run out into the bark. Stain one such section (from the slender portion of the root) with iodine, and sketch it as seen under a low power of the microscope. Where is the starch of this root mainly stored?

46. *Use of the Nourishment stored in Fleshy Roots.* — The parsnip, beet, carrot, and turnip are *biennial plants;* that is, they produce seed during the second summer or fall after they are planted.

The first season's work consists mainly in producing the nourishment which is stored in the roots. To such storage is due their characteristic fleshy appearance. If this root is

[1] The examination of the minute structure of the root is purposely made very hasty, since the detailed study of the structural elements can be made to better advantage in the stem.

planted in the following spring, it feeds the rapidly growing stem which proceeds from the bud at its summit, and an abundant crop of flowers and seed soon follows; while the root, if examined in late summer, will be found to be withered, with its store of reserve material quite exhausted.

The roots of the dahlia, Fig. 20, and of many other *perennials*, or plants which live for many years, contain much stored plant-food. Such plants die to the ground at the beginning of winter, and in spring make a rapid growth from the materials laid up in the roots.

FIG. 20. — Roots of Dahlia, thickened and containing Stored Nourishment.

s, cut-off stems of the plant.

47. *Extent of the Root-System.* — The total length of the roots of ordinary plants is much greater than is usually supposed. They are so closely packed in the earth that only a few of the roots are seen at a time during the process of transplanting, and when a plant is pulled or dug up in the ordinary way, a large part of the whole mass of roots is broken off and left behind. A few plants have been carefully studied to ascertain the total weight and length of the roots. Those of winter wheat have been found to extend to a depth of seven feet. By weighing the whole root-system of a plant and then weighing a known length of a root of average diameter, the total length of the roots may be estimated. In this way the roots of an oat plant have been calculated to measure about 150 feet; that is, all the roots, if cut off and strung together end to end, would reach that distance.

Single roots of large trees often extend horizontally to great distances, but it is not often possible readily to trace the entire depth to which they extend. Roots of oak trees

have been observed penetrating horizontal tunnels in a mine at a depth of about fifty feet.

The total absorbing surface of the roots of a tree must be enormous, since it is greatly increased by the presence of the root-hairs.

48. *Fitness of the Root for its Position and Work.* — The distribution of material in the woody roots of trees and shrubs shows many adaptations to the conditions by which the roots are surrounded. The growing tip of the root, as it pushes its way through the soil, is exposed to bruises; but these are largely warded off by the root-cap. The corky layer which covers the outside is remarkable for its power of preventing evaporation. It must be of use in retaining in the root the moisture which otherwise might be lost, on its way from the deeper rootlets (which are buried in damp soil) through the upper portions of the root-system, about which the soil is often very dry.

49. *Propagation by means of Roots.* — Some familiar plants are usually grown from roots or root-cuttings.

Experiment 14. — Bury a sweet potato or a dahlia root in damp sand, and watch the development of sprouts from adventitious buds. One sweet potato will produce several such crops of sprouts, and every sprout may be made to grow into a new plant. It is in this way that the crop is started wherever the sweet potato is grown for the market.

50. *Absorption of Water by Roots.* — Many experiments on the cultivation of corn, wheat, oats, beans, peas, and other familiar plants in water have proved that some plants, at any rate, can thrive very well on ordinary lake, river, or well water, together with the food which they absorb from the air (Chapter XII). Just how much water some kinds of plants give off (and therefore absorb) per day will be discussed when the uses of the leaf are studied. For the present it is sufficient to state that even an annual plant during its life-time absorbs through the roots very many times its own

weight of water. Grasses have been known to take in their weight of water in every twenty-four hours of warm, dry weather. This absorption takes place mainly through the root-hairs, which the student has examined as they occur in the seedling plant, and which are found thickly clothing the younger and more rapidly growing parts of the roots of mature plants. Some idea of their abundance may be gathered from the fact that on a rootlet of corn grown in a damp atmosphere, and about $\frac{1}{17}$ inch in diameter, 480 root-hairs have been counted on each hundredth of an inch in length. The walls of the root-hairs are extremely thin, and they are free from any holes or pores which can be seen even by the highest power of the microscope, yet the water of the soil penetrates very rapidly to the interior of the root-hairs. The soil-water brings with it all the substances which it can dissolve from the earth about the plant; and the closeness with which the root-hairs cling to the particles of soil, as shown in Fig. 19, must cause the water which is absorbed to contain more foreign matter than underground water in general does, particularly since the roots give off enough weak acid from their surface to corrode the surface of stones which they enfold or cover.

51. *Osmose.*— The process by which two liquids separated by membranes pass through the latter and mingle is called *osmose.*

52. ***Experiment 15.**** *Osmose shown by an Egg.* — Cement to the smaller end of an egg a bit of glass tubing about six inches long and about $\frac{3}{16}$ inch inside diameter. Sealing wax or a mixture of equal parts of beeswax and rosin melted together will serve for a cement.

Chip away part of the shell from the larger end of the egg, place it in a wide-mouthed bottle or a small beaker full of water, as shown in Fig. 21, then very cautiously pierce a hole through the upper end of the egg-shell by pushing a knitting-needle down through the glass tube.

Watch the apparatus for some hours and note the gradual rise of the contents of the egg in the tube.[1]

[1] Testing the contents of the beaker with nitrate of silver solution will then show the presence of a little common salt in the water.

The rise of liquid in the tube is evidently due to water making its way through the thin membrane which lines the egg-shell, although this membrane contains no pores visible even under the microscope.

53. *Experiment 16.* *Osmose shown by a Begonia Leaf.*—Place a little powdered sugar on the upper surface of a thick begonia leaf under a small bell glass. Watch for several days to see whether moisture from the inside of the leaf affects the sugar. The *upper* surface of this leaf contains no pores, even of microscopic size.

FIG. 21. — Egg on Beaker of Water, to show Osmose.

54. *Inequality of Osmotic Exchange.*—The nature of the two liquids separated by any given membrane determines in which direction the greater flow shall take place.

If one of the liquids is pure water and the other is water containing solid substances dissolved in it, the greater flow of liquid will be away from the pure water into the solution, and the stronger or denser the latter, the more unequal will be the flow. This principle is well illustrated by the egg-osmose experiment. Another important principle is that substances which readily crystallize, like salt or sugar, pass rapidly through membranes, while jelly-like substances, like white of egg, can hardly pass through them at all.

55. *Osmose in Root-Hairs.*—It is very easy to understand, from the principles just stated, that the soil-water (which is like ordinary spring or well water), separated by the delicate walls of the root-hairs and a thin lining of jelly-like living matter from the more or less sugary or mucilaginous sap inside them, will pass rapidly into the plant, while very little of the sap will come out. Probably most of the selective action, which causes the flow of liquid through the root-hairs to be almost wholly inward, is due mainly to the living layer of proteid material known as *protoplasm* (Chapter XIII), which

covers the inner surface of the cell-wall of the root-hair. When the student has learned how active a substance protoplasm often shows itself to be, he will not be astonished to find it behaving almost as though it were possessed of intelligence and will. Traveling by osmotic action from cell to cell, a current of water derived from the root-hairs is forced up through the roots and into the stem, just as the contents of the egg was forced up into the tube shown in Fig. 21.

56. *Root Pressure.* — The force with which the upward flowing current of water presses may be estimated by attaching a mercury gauge to the root of a tree, or the stem of a small sapling. This is best done in early spring after the thawing of the ground, but before the leaves have appeared. In Fig. 22 the apparatus is shown attached to the stem of a dahlia. The large glass tube *W*, filled with mercury up to the level *g* and with water from *g* to near *s*, is fastened tightly to the cut stem at *s*. As water absorbed by the roots is forced over into *W*, the mercury level in *Q* will rise higher and the difference of level in the two mercury-columns will measure the root pressure. For every foot of difference in level there must be a pressure of nearly six pounds per square inch on the stump at the base of the tube *g*.

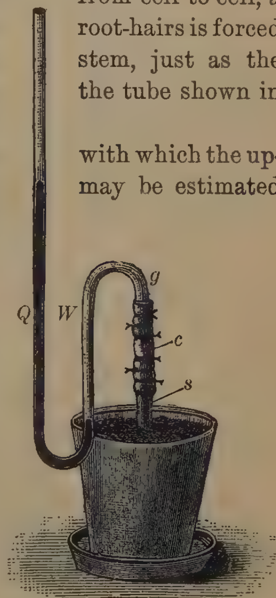


FIG. 22. — Apparatus for Measurement of Root Pressure.

s, cut-off stem of dahlia; *c*, a piece of rubber tubing slipped over the stump *s* and the glass tube *g* and tied fast; *g*, bent glass tube; *W*, water (sap forced up by the roots); *Q*, mercury-column sustained by the root pressure.

A black-birch root tested in this way at the end of April has given a root pressure of 37 pounds to the square inch. This would sustain a column of water about 86 feet high.

CHAPTER V.

Stems.

57. *What the Stem is.* — The work of nourishing the plant is done mainly by the roots and the leaves. The stem is that part or organ of the plant which serves to bring roots and leaves into communication with each other. In most flowering plants the stem also serves the important purpose of lifting the leaves up into the sunlight, where alone they best can do their especial work.

The student has already, in Chapter II, learned something of the development of the stem and the seedling; he has now to study the external appearance and internal structure of the mature stem. Much in regard to these can conveniently be learned from the examination of twigs and branches of our common forest trees in their winter condition.

58. *The Horse-Chestnut Twig.*[1] — Procure a twig of horse-chestnut eighteen inches or more in length. Make a careful sketch of it, trying to bring out the following points:

(1) The general character of the bark.

(2) The large leaf-scars (marking the places where the bases of leaf-stalks were attached) and the number and position of the dots on these scars.

(3) The ring of narrow scars around the stem in one or more places,[2] and the different appearance of the bark above and below such a ring. See Fig. 23, *b sc.*

(4) The buds at the upper margin of each leaf-scar and the strong terminal bud at the end of the twig.

[1] Where the buckeye is more readily obtained it will do very well. Hickory twigs answer the same purpose, and the latter is a more typical form, having alternate buds. The magnolia or the tulip tree will do. The student should (sooner or later) examine at least one opposite and one alternate-leaved twig.

[2] A very vigorous shoot may not show any such ring.

(5) The flower-bud scar, a concave impression, to be found in the angle produced by the forking of two twigs, which form, with the branch from which they spring, a Y-shaped figure.

(6) (On a branch larger than the twig handed round for individual study) the mode of origin of the twigs from the branch; — make a separate sketch of this.

The portion of stem which originally bore any two pairs of leaves is called a *node*, and the portions of stem between nodes are called *internodes*.

Describe briefly in writing alongside the sketches any observed facts which the drawings do not show.

If your twig was a crooked, rough-barked, and slow-growing one, exchange it for a smooth, vigorous one and note the differences. Or if you sketched a quickly grown shoot, exchange for one of the other kind.

FIG. 23. — A Quickly grown Twig of Cherry, with Lateral and Terminal Buds in October.
b sc, bud-scale scars. All above these scars is the growth of the spring and summer of the same year.

Answer the following questions:

(*a*) How many inches did your twig grow during the last summer?
How many in the summer before?
How do you know?
How many years old is the whole twig given you?

(*b*) How were the leaves arranged on the twig?
How many leaves were there?
Were they all of the same size?

(*c*) What has the mode of branching to do with the arrangement of the buds? with the flower-bud scars?

(*d*) The dots on the leaf-scars mark the position of the bundles of ducts and wood-cells which run from the wood of the branch through the leaf-stalk up into the leaf.

59. *Twig of Beech.* — Sketch a vigorous young twig of beech in its winter condition, noting particularly the respects in which it differs from the horse-chestnut. Describe in writing any facts not shown in the sketch. Notice that the buds are not opposite, nor is the next one above

any given bud found directly above it, but part way round the stem from the position of the first one. Ascertain, by studying several twigs, which bud is above the first and how many turns round the stem are made in passing from the first to the one directly above it.

Observe with especial care the difference between the beech and the horse-chestnut in mode of branching, as shown in a large branch provided for the study of this feature.

FIG. 24.—Opposite Branching in a very Young Sapling of Ash.

60. *Relation of Leaf-Arrangement to Branching.*[1] — This difference depends on the fact that the leaves of the horse-chestnut were arranged in pairs, on opposite sides of the stem, while those of the beech were not in pairs. Since the buds are found at the upper edges of the leaf-scars, and since most of the buds of the horse-chestnut and the beech are leaf-buds and destined to form branches, the mode of branching and ultimately the form of the tree must depend largely on the arrangement of leaves along the stem.

61. *Opposite Branching.* — In trees the leaves and buds of which are opposite, the tendency will be to form twigs in two rows about at right angles to each other along the sides of the branch, as shown in Fig. 24.

[1] The teacher will do well to make constant use, in the study of branches and buds, of Miss Newell's *Outlines of Lessons in Botany*, Part I. The student can make out for himself, with a little guidance from the teacher, most of the points

This arrangement will not usually be perfectly carried out, since some of the buds may never grow, or some may grow much faster than others and so make the plan of branching less evident than it would be if all grew alike.

62. *Alternate Branching.* — In trees like the beech the twigs will be found to be arranged in a more or less regular spiral line about the branch. This, which is known as the *alternate* arrangement (Fig. 25), is more commonly met with in trees and shrubs than the *opposite* arrangement. It admits of many varieties, since the spiral may wind more or less rapidly round the stem. In the apple, pear, cherry, poplar, oak, and walnut, one passes over five spaces before coming to a leaf which is over the first, and in doing this it is necessary to make two complete turns round the stem, Fig. 77.

FIG. 25.—Alternate Branching in a very Young Apple Tree.

63. *Growth of the Terminal Bud.* — In some trees the terminal bud from the very outset keeps the leading place, and the result of this mode of growth is to produce a slender, upright tree, with an *excurrent* trunk like that of Fig. 26, II.

In such trees as the apple and many oaks the terminal bud has no preëminence over others, and the form of the tree is round-topped and spreading, *deliquescent* like Fig. 26, I.

Most of the larger forest trees are intermediate between these extremes, like Fig. 27.

which Miss Newell suggests. If the supply of material is abundant, the twigs employed in the lessons above described need not be used further, but if material is scanty, the study of buds may at once be taken up.

Branches get their characteristics to a considerable degree from the relative importance of their terminal buds. If these are mainly flower-buds, as is the case in the horse-chestnut, the tree is characterized by frequent forking, and has no long horizontal branches.

If the terminal bud keeps the lead of the lateral ones, but the latter are numerous and most of them grow into slender twigs, the delicate spray of the elm and many birches is produced, Fig. 28.

I. II.

FIG. 26.—I, An American Elm with Deliquescent Trunk. II, Cottonwood Poplars with Excurrent Trunks.

The general effect of the branching depends much upon the angle which each branch or twig forms with that one from which it springs. The angle may be quite acute, as in the birch; or more nearly a right angle, as in the ash, Fig. 24.

It is these differences that help to give to leafless woods in winter their unending variety and beauty.

64. *Indefinite Annual Growth.* — In most of the forest trees, and in the larger shrubs, the wood of the branches is matured and fully developed during the summer, and pro-

tected buds are formed on the twigs to their very tips. In other shrubs — for example, in the sumach, the raspberry, and blackberry — the shoots continue to grow until their soft and partly matured tips are killed by the frost. Such a mode of growth is called *indefinite annual growth*, to distinguish it from the *definite annual growth* of most trees.

65. *Trees, Shrubs, and Herbs.* — Plants of the largest size, with a main trunk of a woody structure, are called *trees*. *Shrubs* differ from trees in their smaller size, and generally in their more forking and divided stem. The witch-hazel, the dogwoods, and the alders, for instance, are most of them classed as shrubs for this reason, though in height some of them equal the smaller trees. Some of the smallest shrubby plants, like the blueberry, the wintergreen, and the trailing arbutus, are only a few inches in height, but are ranked as shrubs because their woody stems do not die quite to the ground in winter.

FIG. 27. — A White-Oak Tree, with Trunk somewhat Deliquescent.

Herbs are plants whose stems above ground die every winter.

66. *Annual, Biennial, and Perennial Plants.* — *Annual* plants are those which live but one year, *biennials* those which live two years or nearly so (see § 46).

Some annual plants may be made to live over winter, flowering in their second summer. This is true of winter wheat and rye among cultivated plants.

Perennial plants live for a series of years. Many kinds of trees last for centuries. The Californian giant redwoods, or Sequoias, which reach a height of over 300 feet under favorable circumstances, live nearly 2000 years; and some monstrous cypress trees found in Mexico were thought by Professor Asa Gray to be from 4000 to 6000 years old.

FIG. 28.—Twigs and Branches of the River Birch.

67. *Stemless Plants.*—The so-called *stemless plants*, like the dandelion, Fig. 29, and some violets, are not really stemless at all, but send out their leaves and flowers from a very short stem which hardly rises at all above the surface of the ground.

Now, as will be shown later (§ 241) plants live subject to a very fierce competition among themselves and exposed to almost constant attacks from animals.

Any plant which can grow in safety under the very feet of grazing animals will be especially likely to make its way in the world, since there are many places where it can flourish while ordinary plants would be destroyed. The bitter, stemless dandelion, which is almost uneatable for most animals, unless cooked, which lies too near the earth to be fed upon by grazing animals, and which bears being trodden on with impunity, is a type of a large class of hardy weeds.

And while plants with long stems find it to their account to reach up as far as possible into the sunlight, the cinquefoil,

the white clover, the dandelion, the spurges, the knot-grass, and hundreds of other kinds of plants have found safety in hugging the ground.

68. *Climbing and Twining Stems.*[1] — Since it is essential to the health and rapid growth of most plants that they should have free access to the sun and air, it is not strange that many should resort to special devices for lifting themselves above their neighbors. In tropical forests, where the darkness of the shade anywhere beneath the tree-tops is so great that few flowering plants can thrive in it, the climbing plants or *lianas* often run like great cables for hundreds of

FIG. 29. — The Dandelion; a so-called Stemless Plant.

feet before they can emerge into the sunshine above, as those shown in the frontispiece have probably done. In temperate climates no such remarkable climbers are found, but many plants raise themselves for considerable distances. The principal means to which they resort for this purpose are:

(1) Producing roots at many points along the stem above ground and climbing on suitable objects by means of these, as in the English ivy, Fig. 14.

[1] See Kerner and Oliver's *Natural History of Plants*, vol. I, p. 669.

(2) Laying hold of objects by means of tendrils or *twining* branches or *leaf-stalks,* as shown in Figs. 30, 31.

(3) Twining about any slender upright support, as shown in Fig. 32.

69. *Tendril-Climbers.*—The plants which climb by means of tendrils are very interesting subjects for study, but they cannot usually be managed very well in the schoolroom. Continued observation soon shows that the tips of tendrils sweep slowly about in the air until they come in contact with some object about which they can coil themselves. After the tendril has taken a few turns about its support, the free part of the tendril coils into a spiral and thus draws the whole stem toward the point of attachment as shown in Fig. 30. Some tendrils are leaves or stipules, as shown in Fig. 91; others are modified stems.

FIG. 30.—Coiling of a Tendril of Bryony.
x, portion coiled around a twig; *w*, *w'*, places where direction of coiling reverses; *u*, uncoiled portion of tendril.

70. *Twiners.*—Only a few of the upper internodes of the stem of a twiner are concerned in producing the movements of the tip of the stem. This is kept revolving in an elliptical or circular path until it encounters some roughish and not too stout object, about which it then proceeds to coil itself. The direction of the coiling varies in different kinds of climbers, some following the course shown in the figure of the hop on the next page, others, as the morning-glory, taking the opposite course.

71. *Underground Stems.*—Stems which lie mainly or wholly underground are of frequent occurrence and of many kinds.

In the simplest form of *rootstock*, Fig. 33, such as is found in some mints and in many grasses and sedges, the real nature of the creeping stem is shown by the presence upon its surface of many scales which are reduced leaves. In the stouter rootstocks, like that of the iris, Fig. 34, this stem-like character is less evident. The potato is an excellent example of the short and much thickened underground stem known as a *tuber*.

It may be seen from Fig. 35 that the potatoes are none of them borne on true roots, but only on subterranean branches, which are stouter and more cylindrical than most of the roots.

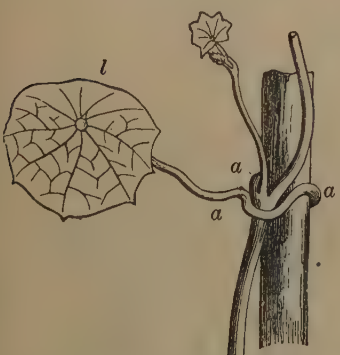


Fig. 31.—Coiling of Petiole of Dwarf Tropæolum; *l*, leaf; *a*, petiole.

Fig. 32.—Twining Stem of Hop.

Bulbs, whether coated like those of the onion or scaly like those of the hyacinth, Fig. 36, are merely very short and stout underground stems, covered with closely crowded scales or layers which represent leaves or the bases of leaves, Fig. 37.

The variously modified forms of underground stem just discussed, illustrate in a marked way the storage of nourish-

ment during the winter (or the rainless season, as the case may be) to secure rapid growth during the active season. It is interesting to notice that nearly all of the early-flowering herbs in temperate climates, like the crocus, the snowdrop, the spring-beauty, the tulip, and the skunk-cabbage, owe their early-blooming habit to richly stored underground stems of some kind, or to thick, fleshy roots.

FIG. 33.—Rootstock of a Sedge.
The young, advancing shoot is seen at the left; in the centre is a cluster of leaves rising above ground; further to the right similar clusters would be found springing from the same rootstock.

FIG. 34.—Roots, Rootstocks, and Leaves of Iris.

72. *Condensed Stems.*—The plants of desert regions require above all protection from the extreme dryness of the surrounding air, and, usually, from the excessive heat of the sun. Accordingly, many desert plants are found quite destitute of ordinary foliage, exposing to the air only a small surface of green rind. In the melon-cactuses, Fig. 38, the stem appears reduced to the shape in which the

least possible surface is presented by a plant of given bulk, — that is, in form. Other cactuses are more or less cylindrical or prismatic, others still consist of flattened joints, but all agree in offering much less surface to the sun and air than is exposed by an ordinary leafy plant.

FIG. 35. — Part of a Potato Plant.

The dark tuber in the middle is the one from which the plant has grown.

73. *Leaf-like Stems.* — The flattened stems of some kinds of cactus (especially the common, showy *Phyllocactus*) are sufficiently like fleshy leaves, with their dark green color and imitation of a midrib, to pass for leaves among people who are not botanists. There are, however, a good many cases in which the stem takes on a more strikingly leaf-like form. The common asparagus sends up in spring shoots that bear large scales which are really reduced leaves. Later in the season, what seem like thread-like leaves cover the much-branched mature plant, but these green threads are actually minute branches, which per-

I. II.

FIG. 36. — I, Bulb of Hyacinth. II, the same split lengthwise.

form the work of leaves. The familiar greenhouse climber, wrongly known as smilax (properly called Myrsiphyllum), bears a profusion of what appear to be delicate green leaves, Fig. 39. Close study, however, shows that these are really short, flattened branches, and each of them springs from the axil of a true leaf, *l*, in the form of a minute scale. Some-

FIG. 37.—Longitudinal Section of an Onion Leaf.
z, thickened base of leaf, forming a bulb-scale; *s*, thin sheath of leaf; *l*, *i*, blade of the leaf; *h*, hollow interior of blade.

FIG. 38.—A Melon-Cactus.

times, as shown at *f*, a flower and a leaf-like branch spring from the axil of the same scale.

Branches which, like those of the Myrsiphyllum, so closely resemble leaves as to be almost indistinguishable from them are called *cladophylls.*

74. *Modifiability of the Stem.*—The stem may, as in the tallest trees, in the great lianas of South American forests, seen in the frontispiece, or the rattan of Indian jungles, reach a length of many hundred feet, or it may in such "stemless"

plants as the primrose and the dandelion be cut down to a fraction of an inch in length. It may take on apparently root-like forms, as in many grasses and sedges, or become thickened by underground deposits of starch and other plant-food, as in the iris, the potato, and the crocus. Condensed forms of stem may exist above ground, or, on the other hand,

FIG. 39.—Stem of "Smilax" (Myrsiphyllum).
l, scale-like leaves; *Cl*, cladophyll, or leaf-like branch, growing in the axil of the leaf; *ped*, flower-stalk, growing in the axil of a leaf.

branches may be flat and thin enough closely to imitate leaves. In short, the stem manifests great readiness in adapting itself to the most varied conditions of existence.

CHAPTER VI.

Structure of the Stem.

Stem of Dicotyledonous Plants.

I.

75. *General Structure.*—Cut smooth, rather thick, sections from a twig of apple one year old. Place in focus under the magnifying glass and make a sketch to show the relative position and amount of bark, wood, and pith.

From a twig of cherry a year or two old peel off the brown outer coating. This is the *corky layer* of the bark, more distinct in the cherry tree than in the apple.

Notice on the outer surface of the twig the rough oval or lens-shaped spots. These are the *lenticels*, spots in which the inner and more porous layers of the bark protrude through the corky layer and allow air to penetrate to the interior of the branches.[1] Notice the *green layer* or middle bark in the peeled portion of the cherry twig, and expose this layer in the apple twig by carefully scraping off the corky layer.

Cut off, as smoothly as possible, a small branch of hickory and one of white oak above and below each of the rings of scars already mentioned (§ 58), and count the rings of wood above and below each ring of scars.

How do the numbers correspond? What does this indicate?

Count the rings of wood on the cut-off ends of large billets of some of the following woods: locust, chestnut, sycamore, oak, hickory.

Do the successive rings of the same tree agree in thickness?

Why? or why not?

Does the thickness of the rings appear uniform all the way round the stick of wood? If not, the reason in the case of an upright stem (trunk) is perhaps that there was a greater spread of leaves on the side where the rings are thickest[2] or because there was unequal pressure, caused by bending before the wind.

Do the rings of any one kind of tree agree in thickness with those of all the other kinds? What does this show?

In all the woods examined look for:

(*a*) Contrasts in color between the heartwood and the sapwood.[3]

[1] See Gregory's *Plant Anatomy*, pp. 138–141. [2] See § 145.

[3] This is admirably shown in black walnut, barberry, and osage orange.

(*b*) The narrow lines running in very young stems pretty straight from pith to bark, in older wood extending only a little of the way from centre to bark, the *medullary rays*, shown in Fig. 40.[1]

(*c*) The wedge-shaped masses of wood between these.

(*d*) The holes which are so grouped as to mark the divisions between successive rings. These holes indicate the cross-sections of *vessels* or *ducts* (§ 82). Note the distribution of the vessels in the rings to which they belong, compare this with Figs. 40, 41, and decide at what season of the year the largest ducts are mainly produced. Cut off a grapevine several years old and notice the great size of the vessels. Examine the smoothly planed surface of a billet of red oak that has been split through the middle of the tree (quartered oak), and note the large shining plates formed by the medullary rays.

Look at another stick that has been planed away from the outside until a good-sized flat surface is shown, and see how the medullary rays are here represented only by their edges.

FIG. 40. — Cross-Section of Oak Wood as seen with the Magnifying Glass.
J, *J*, the annual rings.[2]

II.

76. *Details of Structure; Cross-Section.* — Cut from shoots of the apple tree, ranging in age from one to five years, a number of sections. These should be as thin as they can be made without breaking up. It will save time to make at one time a good many sections of any woody part of the plant that is to be examined.[3]

For examination with the lowest powers, cylinders $\frac{1}{4}$ to $\frac{1}{2}$ inch long cut smoothly from the twig to be examined, and viewed as opaque objects, will answer well.

[1] These and many other important things are admirably shown in the thin wood-sections furnished for $4 per set of 24 by R. B. Hough, Lowville, N. Y.

[2] The shading in fine lines at *J* would be rendered more naturally by dots.

[3] If time allows, the students should cut their own sections: frequently this will be impracticable. Sections not needed for the current lesson may be put in 50 per cent alcohol or other preservative fluid in wide-mouthed bottles *carefully labeled* and kept for future use. For a list of sections see Appendix C.

Examine each thin section first with a power of about 25 diameters, then with a power of from 100 to 200 diameters. With the lower power, sketch a one-year-old section, labeling in your sketch:

(*a*) The corky layer of the bark.
(*b*) The green layer.
(*c*) The masses of bast fibres.
(*d*) The wood, with the medullary rays and vessels.
(*e*) The pith.

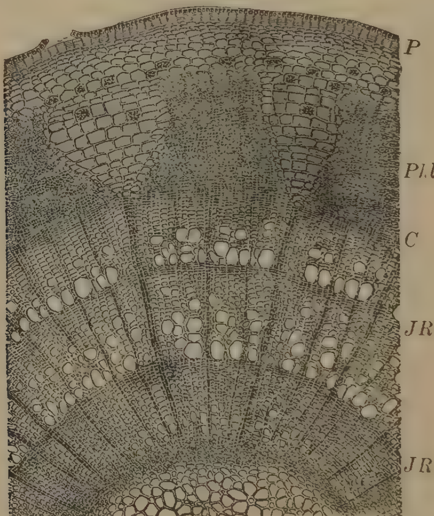


FIG. 41.—Cross-Section of a Three-year-old Linden Twig. (Much magnified.) *P*, epidermis and corky layer of the bark; *Phl*, bast; *C*, cambium layer; *JR*, annual rings of wood.

After examining this section with the higher power and noting particularly the appearance of the wood-cells, replace it by a section of stem at least four years old.

Sketch this as seen with the low power, then substitute the higher power and study the *inner bark*, noting especially the masses of very thick-walled *bast-cells*.

What are the principal differences between the structure of the apple twig, so far as you have examined it, and the structure of a linden twig, as shown in Fig. 41?

Make a thin section of the stem of grapevine or elder a year or two old and study the pith with a power of 50 or 100 diameters. Sketch it.

Fig 42.

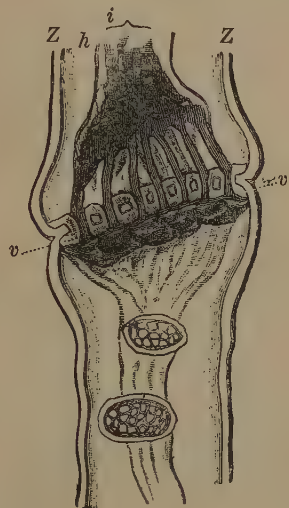


Fig. 43.

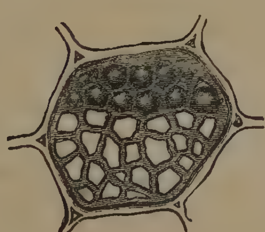


Fig. 44.

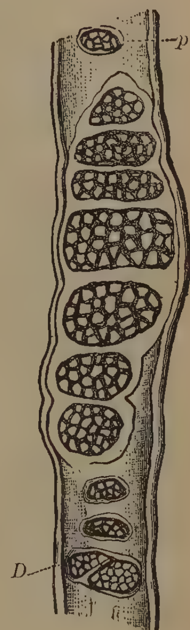


Fig. 45.

Fig. 42. — Portion of a Sieve-Tube, showing one whole cell and parts of two others.

Fig. 43. — Longitudinal Section through Sieve-Tube of the Gourd. *Z*, cell-wall; *h*, outer coating of protoplasmic cell-contents *i*; *v*, sieve-plate.

Fig. 44. — Transverse Section of a Sieve-Plate like that shown at *v*.

Fig. 45. — Part of Longitudinal Section of a Sieve-Tube of Linden, showing sieve-plates *p* on the sides of the tube (two of which are also shown on Fig. 43).

(All greatly magnified.)

77. *Sieve-Tubes.* — Grouped together with the bast fibres of the stem there occur a peculiar and very important set of vessels called *sieve-tubes.* The student cannot easily make these out from sections of ordinary stems, but it is not difficult to understand their structure in a general way. These tubes arise from the partial union of large cells which stand in rows, united end to end, as shown in Figs. 42, 43. The partitions between adjacent cells gradually become perforated with holes, forming a *sieve-plate,* like that shown in Fig. 44. Sometimes the walls of sieve-tubes are more or less fully covered with perforations, as shown in Fig. 45.

Continuity of the Living Cell-Contents. — It was formerly supposed that cells of plants were entirely shut off from each other while living. Recently, careful investigations have shown that very generally, especially in the expanded bases of the leaf-stalks of leaves which move of their own accord and in sieve-cells, there is a direct connection of the contents of one cell with another. The *protoplasm,* or semi-fluid layer with which all active cells are lined, and in which their life and working-power resides (Chapter XIII), extends in delicate threads through the cell walls, and connects in all directions with the protoplasm of other cells.

Fig. 46. — Side View of Part of one of the Medullary Rays of Maple Wood. (Much magnified.)

78. *Longitudinal Section of the Stem.* — The knowledge of stem-structure that can be gained from a longitudinal section of any kind of wood depends upon the way in which the section is cut; that is, whether it is at right angles to the annual rings (*radial section*), or parallel to the rings (*tangential section*). The wood-cells, of which the student has in the cross-section seen only the cut-off ends, appearing as circular or

oval figures, now show the whole length of the cell, and he may study the way in which they interlock at the ends.

In the radial section the medullary rays will frequently look somewhat like portions of brickwork, as shown in Fig. 46.

In the tangential section, only the cut-off edges of the medullary rays will be seen, as shown in Fig. 47.

79. *Separate Wood-Cells.* — The complete outline of wood-cells and bast-cells is most easily made out by examining cells which have been separated from each other by soaking wood or bark, as the case may be, in a mixture of chlorate of potash and nitric acid until it can be easily picked to pieces in water and viewed under the microscope. In this way such cells as those shown in Fig. 48 may be isolated and studied.

FIG. 47. — Longitudinal Section of Mahogany at right angles to the Medullary Rays, showing their cut-off ends.[1] (Much magnified.)

80. *Ducts of Various Forms.* — In most of the hard-woods the ducts are poorly shown in the longitudinal section, since they usually become much split and broken in the process of cutting the section.

Study and sketch some of the following, as seen under a moderately high power :

Radial longitudinal section of wood of tulip tree, longitudinal section of stem of bracken fern (Pteris), stem of castor-oil plant (Fig. 49), of peduncle of banana, or of root of chicory or licorice.

81. *Kinds of Tissue.* — The student has now become acquainted with a few of the many kinds of cells found in plants, and has begun to see how they are grouped together

[1] The apparently vacant spaces at the ends of the lens-shaped sections of the medullary rays are in most woods filled with cells, like the rest of the section.

in masses to make up the bulk of the plant. Masses of cells which have a common work to do are called *tissues.*[1] Two of the most important forms of tissue are *parenchyma* and *prosenchyma.* Parenchyma is found in the seed, in the bark (constituting the greater portion of all young bark), in the medullary rays and the pith, and in the leaf. Parenchyma cells are usually roundish or somewhat cubical or twelve-sided in shape.

From the fact that a sphere surrounded by other spheres is touched by twelve others, parenchyma cells, which begin their existence in a somewhat globular form, often end by growing approximately twelve-sided from the pressure of their neighbors. Prosenchyma cells are long, often thick-walled, and interlock at the ends, so as to leave but few and small intercellular spaces. They form the fibrous part of bark and of most kinds of wood.

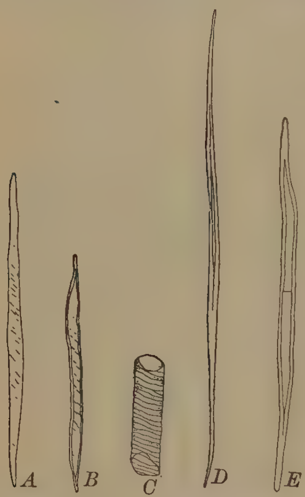


FIG. 48. — *A*, *B*, *C*, *D*, Isolated Wood-Cells and Bast-Cells of Linden.

A, *B*, wood fibres; *C*, piece of a vessel; *D*, bast fibre; *E*, a partitioned, woody fibre from European ivy. (Much magnified.)

82. *Uses of the Components of the Stem.* — There is a marked division of labor among the various groups of cells that make up the stem of ordinary dicotyledons, particularly in the stems of trees, and it will be best to explain the uses of the kinds of cells as found in trees, rather than in herbaceous plants.

A few of the ascertained uses of the various tissues are these:

[1] See Gregory's *Plant Anatomy*, Chapter IV.

The pith forms a large part of the bulk of very young shoots, since it is a part of the fundamental tissue amid which the fibro-vascular bundles arise. In mature stems it becomes rather unimportant, though it often continues for a long time to act as a storehouse of nourishment.

The medullary rays, in the young shoot, serve as a channel for the transference of water and plant-food in a liquid form across the stem, and they often contain much stored nourishment.

The vessels carry water and air through the stem.

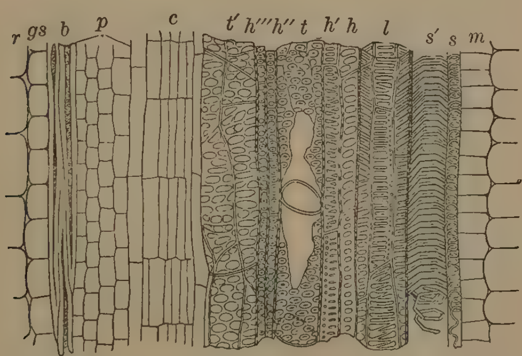


FIG. 49. — Longitudinal Section of a Fibro-Vascular Bundle of the Castor-Oil Plant. *r*, *gs*, *b*, *p*, various layers of the bark; *c*, cambium; *t l*, *s*, *s′*, various kinds of vessels; *h*, *h′*, *h″*, *h‴*, wood-cells; *m*, pith. (Much magnified.)

The wood-cells of the heartwood are useful only to give stiffness to the stem. Those of the sapwood in addition to this work have to carry most of the water from the roots to the leaves and other distant portions of the plant.

The cambium layer is the region in which the annual growth of the tree takes place, § 84.

The most important portion of the inner bark is that which consists of sieve-tubes, for in these digested and elaborated plant-food is carried from the leaves toward the roots.

The green layer of the bark in young shoots does much toward collecting and preparing the food of the plant from air and water, but this work may be best explained in connection with the study of the leaf, Chapter XII.

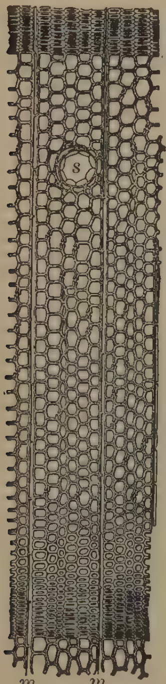


FIG. 50.—Cross-Section of Fir Wood.

s, a resin passage; *m*, medullary rays. (Much magnified.)

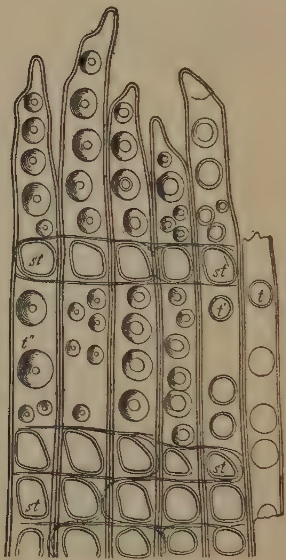


FIG. 51.—Longitudinal Radial Section through a Rapidly Growing Young Branch of Pine.

t, *t'*, *t''*, bordered pits on wood-cells; *st*, large pits where medullary rays lie against wood-cells. (Much magnified.)

Finally, the corky layer of the bark serves to a considerable extent as a protection against sudden changes of temperature and aids greatly in preventing evaporation of water on its way along the stem.

83. *Stem of Conifers.*[1] — Sketch the end of a cut-off billet of hard pine or red cedar. Study the cut surface with a magnifying glass and decide whether any of the parts readily found in the wood of the coarser-grained hard-woods are absent from coniferous wood.

Under a power of 100 or more diameters it is easy to see what it is that marks off one annual ring from another.

Study the section, compare it with Fig. 50, and state the difference between spring wood and fall wood.

Sketch the whole cross-section, moderately magnified

Examine longitudinal sections, both radial and tangential, of pine, spruce, fir, or red cedar.[2]

Sketch a radial section and a tangential one, labeling the medullary rays and the cells of the wood, with their circular markings, as shown in Fig. 51.

84. *The Early History of the Stem.* — In the earliest stages of the growth of the stem it consists entirely of thin-walled and rapidly dividing cells. Soon, however, the various kinds of tissue which are found in the full-grown stem begin to appear.

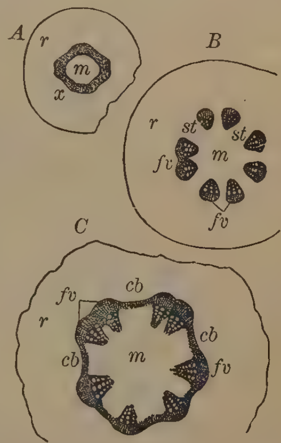


FIG. 52. — Transverse Section through the Caulicle of the Castor-Oil Plant at Various Stages.

A, after the root has just appeared outside the testa of the seed; *B*, after the caulicle is nearly an inch long; *C*, at the end of germination; *r*, cortex (undeveloped bark); *m*, pith; *st*, medullary rays; *fv*, fibro-vascular bundles; *cb*, layer of tissue which is to develop into cambium. (Considerably magnified.)

In Fig. 52 the process is shown as it occurs in the castor bean. At *m*, in *B*, is the central column of pith, surrounded by eight fibro-vascular bundles, *fv*, each of which contains a number of ducts arranged in a pretty regular manner and surrounded by the forerunners of the true wood-cells.

[1] That is, of the cone-bearing trees (mostly evergreens), such as the pines, spruces, cedars, larches, and so on.

[2] Pine shows the large circular pits very plainly, while red cedar shows the medullary rays most clearly, since nearly all its red color lies in these.

In *C*, the section shows a considerable advance in growth: the fibro-vascular bundles are larger and are now connected by a rapidly growing layer of tissue, *cb.*

As growth continues, this layer becomes the *cambium layer*, composed of thin-walled and rapidly dividing cells, as shown in Fig. 41.

85. *Secondary Growth.* — From the inside of the cambium layer the wood-cells and ducts of the mature stem are produced, while from its outer circumference the new layers of the bark proceed. From this mode of increase, the stems of dicotyledonous plants are called *exogenous*, that is, outside-growing. The presence of the cambium layer on the outside of the wood in early spring is a fact well known to the schoolboy who pounds the cylinder cut from an elder, willow, or hickory branch until the bark will slip off and so enable him to make a whistle. The sweet taste of this pulpy layer, as found in the white pine, the slippery elm, and the basswood, is a familiar evidence of the nourishment which the cambium layer contains.

With the increase of the fibro-vascular bundles of the wood the space between them, which appears relatively large in Fig. 52, becomes less and less, and the pith, which at first extended freely out toward the circumference of the stem, becomes compressed into thin plates so as to form medullary rays.

These are, as already stated, of use in storing the food which the plant in cold and temperate climates lays up in the summer and fall for use in the following spring, and in the very young stem they serve as an important channel for the transference of fluids across the stem from bark to pith, or in the reverse direction. On account, perhaps, of their importance to the plants, the cells of the medullary rays are among the longest-lived of all vegetable cells, retaining their vitality in the beech tree sometimes, it is said, for more than a hundred years.

After the inter-spaces between the first fibro-vascular bundles have become filled up with wood, the subsequent growth must take place in the manner shown in Fig. 53. The cambium of the original wedges of wood, *fc*, and the cambium, *ic*, formed between these wedges, continues to grow from its inner and from its outer surface, and thus causes a permanent

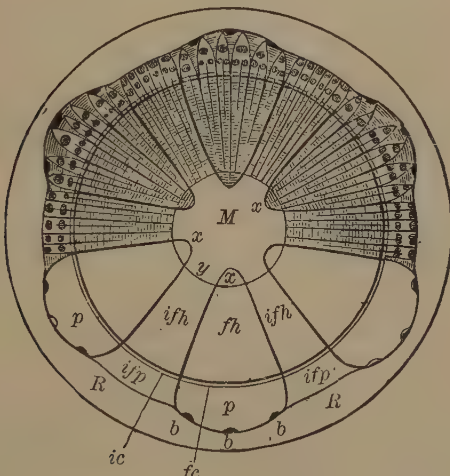


FIG. 53. — Diagram to illustrate Secondary Growth in a Dicotyledonous Stem.

R, the first-formed bark; *p*, mass of sieve-cells; *ifp*, mass of sieve-cells between the original wedges of wood; *fc*, cambium of wedges of wood; *ic*, cambium between wedges; *b*, groups of bast-cells; *fh*, wood of the original wedges; *ifh*, wood formed between wedges; *x*, earliest wood formed; *M*, pith.

increase in the diameter of the stem and a thickening of the bark, which, however, usually soon begins to peel off from the outside and thus soon attains a pretty constant thickness.[1]

86. *Grafting.* — When the cambium layer of any vigorously growing stem is brought in contact with this layer in

[1] See Gregory's *Plant Anatomy*, Chapter VII.

another stem of the same kind or a closely similar kind of plant, the two may grow together to form a single stem or branch. This process is called *grafting*, and is much resorted to in order to secure apples, pears, etc., of any desired kind. A twig from a tree of the chosen variety is grafted on to any kind of tree *of the same species* (or sometimes a related species), and the resulting stems will bear the wished-for kind of fruit.

Stem of Monocotyledonous Plants.

87. *General Structure.* — Cut across a corn-stalk and examine the cut surface with the magnifying glass. Note the firm rind, composed of the epidermis and underlying tissue, the large mass of pith composing the main bulk of the stem, and the *fibro-vascular bundles*, or groups of wood-cells, bast-cells, and vessels.

In what part of the stem are these bundles most abundant?

Split a portion of the stem lengthwise and notice whether the bundles seem to run straight up and down its length. Every fibro-vascular bundle of the stem passes outward through some node in order to connect with some fibro-vascular bundle of a leaf. This fact being known to the student would lead him to expect to find the bundles bending out of a vertical position more at the nodes than elsewhere. Can this be seen in the stem examined?

Observe the enlargement and thickening at the nodes, and split one of these lengthwise to see whether the tissue within it is exactly like that in the internodes. How may the difference, if any, be explained?

Compare with the corn-stalk a piece of palmetto[1] and notice the similarity of structure, except for the fact that the tissue in the palmetto which answers to the pith of the corn-stalk is much darker-colored and harder than corn-stalk pith. Compare also a piece of rattan.

Cut a thin cross-section of the corn-stalk, examine with a moderately high power of the microscope, and note:

(*a*) The rind, composed largely of hard, thick-walled fibres known as *sclerenchyma* fibres;

(*b*) The fibro-vascular bundles, most abundant near the outside, becoming much more scattered toward the centre of the stem;

(*c*) The pith, occupying the intervals between the fibro-vascular bundles.

[1] The pieces which are sold at the druggists' prepared for nail-brushes will serve the purpose well.

Study the bundles in various portions of the section and notice particularly whether the relative amount of surface in each covered by ducts and by thick-walled wood-cells or sclerenchyma cells is everywhere the same.

On the whole the structure of monocotyledonous stems is much simpler than that of dicotyledonous stems. The bundles which they contain are somewhat similar to those which the exogenous or outside-growing stems of dicotyledons form at a very early period of their growth.

But while in exogens these bundles soon unite into a ring of woody tissue, with a cambium layer outside, capable of continual growth inward and outward, in the *endogenous* or inside-growing stems of monocotyledons this is not the case. True cambium is not formed, but the *procambium* which precedes the mature bark-cells and wood-cells is all transformed into cells of bark or of wood, which attain their full size and are then incapable of giving rise to new cells of any kind. Therefore, the stems of such perennials as palms remain unchanged in diameter year after year. Monocotyledonous stems which do increase in diameter from year to year do so by the introduction of new bundles among the old ones. This growth by interposition of new bundles affords some justification for the name endogenous, often given to the monocotyledonous stem.

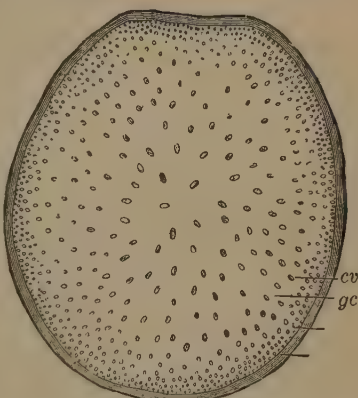


FIG. 54. — Cross-Section of Stem of Indian Corn.

c v, fibro-vascular bundles; *g c*, pithy material between bundles.

88. *Distribution of Material in Monocotyledonous Stems.* — The well-known strength and lightness of the straw of our

smaller grains and of rods of cane or bamboo is due to their form. It can readily be shown by experiment that an iron or steel tube of moderate thickness, like a piece of gas-pipe, or of bicycle-tubing, is much stiffer than a solid rod of the same weight per foot. The oat straw, the cane (of our southern canebrakes), and the bamboo are hollow cylinders: the corn-stalk is a solid cylinder, but filled with a very light pith. The flinty outer layer of the stalk, together with the closely packed sclerenchyma fibres of the outer rind and the frequent fibro-vascular bundles just within this are arranged in a most advantageous way to secure stiffness.

89. ***Experiment 17.*** *Rise of Water in Monocotyledonous Stems.* — Place in red ink the ends of pieces cut from any obtainable monocotyledonous stem, as green brier, or young shoots of asparagus,[1] and watch for an hour or two the rise of the coloring-matter, by taking out pieces of stem from time to time and cutting each back from the upper end until the colored portion is reached. Examine the cut surfaces and the outside of each stem with the glass, and describe exactly the distribution of the coloring-matter.

[1] If the class is studying this subject during the autumn, fresh pieces of corn-stalk will be found to give excellent results.

CHAPTER VII.

Living Parts of the Stem; Work of the Stem.

90. In annual plants generally and in the very young shoots of shrubs and trees there are *stomata* or breathing pores which occur abundantly in the epidermis, serving for the admission of air and the escape of moisture, while the green layer of the bark answers the same purpose that is served by the green pulp of the leaf (Chapter XII). For years, too, the spongy lenticels, which succeed the stomata and occur scattered over the external surface of the bark of trees and shrubs, serve to admit air to the interior of the stem. The lenticels at first appear as roundish spots, of very small size, but as the twig or shoot on which they occur increases in diameter the lenticel becomes spread out at right angles to the length of the stem, so that it sometimes becomes a long transverse slit or scar on the bark, as in the cherry and the birch. But in the trunk of a large tree no part of the bark except the inner layers is alive. The older portions of the bark, such as the highly developed cork of the cork-oak, from which the ordinary stoppers for bottles are made, sometimes cling for years after they are dead and useless, except as a protection for the parts beneath against mechanical injuries or against cold. But in many cases, as in the shellbark hickory and the grapevine, the old bark soon falls off in strips; in birches it finally peels off in bands around the stem.

The cambium layer is very much alive and so is the young outer portion of the wood. Testing this "sapwood," particularly in winter, shows that it is rich in starch and proteids.

The heartwood of a full-grown tree is hardly living, unless some of the medullary rays may retain their vitality, and so wood of this kind is useful to the tree mainly by the stiffness which it gives to the trunk and larger branches, thus preventing them from being easily broken by storms.

91. *Movement of Water in the Stem.* — The student has already learned (§ 50) that large quantities of water are taken up by the roots.

Having become somewhat acquainted with the structure of the stem, he is now in a position to investigate the question how the various fluids, commonly known as sap, travel about in it.[1] It is important to notice that sap is by no means the same substance everywhere and at all times. As it first makes its way by osmotic action inward through the root-hairs of the growing plant it differs but little from ordinary spring water or well water. The liquid which flows from the cut stem of a "bleeding" grapevine which has been pruned just before the buds have begun to burst in the spring, is water with a little mucilaginous or slimy material added. The sap which is obtained from maple trees in late winter or early spring, and is boiled down for syrup or sugar, is still richer in nutritious material than the water of the grapevine, while the elaborated sap which is sent so abundantly into the ear of corn, at its period of filling out, or into the growing pods of beans and peas, or into the rapidly forming acorn or the chestnut, contain great stores of food, suited to sustain plant or animal life.

92. ***Experiment 18.*** *Rise of Water in Exogenous Stems.* — Cut some short branches from a grapevine and stand the lower end of each in red ink; try the same experiment with twigs of oak, ash, or other porous wood, and after some hours examine with the magnifying glass and with the microscope, using the two-inch objective, successive cross-sections of one or more twigs of each kind. Note exactly the portions

[1] See the paper on *The so-called Sap of Trees and its Movements*, by Prof. Chas. R. Barnes, Science, XXI, 535.

through which the ink has traveled. Repeat with several potatoes, cut crosswise through the middle. For the sake of comparison between roots and stems, treat any convenient root, such as a parsnip, in the same way.

Examine longitudinal sections of some of the twigs, the potatoes, and the roots. In drawing conclusions about the channels through which the ink has risen (which are those through which the crude sap most readily travels), bear in mind the fact that a slow soakage of the red ink will take place in all directions, and therefore pay attention only to the strongly colored spots or lines.

What conclusions can be drawn from this experiment as to the course followed by the sap?

From the familiar facts that ordinary forest trees apparently flourish as well after the almost complete decay and removal of their heartwood, and that many kinds will live and grow for a considerable time after a ring of bark extending all round the trunk has been removed, it may readily be inferred that the crude sap in trees must rise through some portion of the newer layers of the wood.

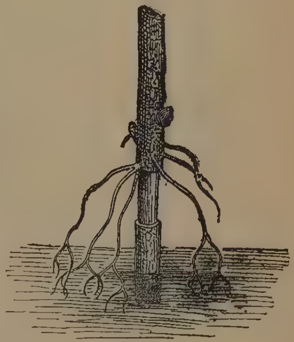


FIG. 55.—A Cutting Girdled and sending down Roots from the Upper Edge of the Girdled Ring.

Most dicotyledonous stems, when stripped of a ring of bark and then stood in water, as shown in Fig. 55, develop roots only at or near the upper edge of the stripped portion,[1] and this would seem to prove that such stems send their building-material — the elaborated sap — largely at any rate down through the bark. Its course is undoubtedly for the most part through the sieve-cells (Figs. 42–45), which are admirably adapted to convey liquids. In addition to these general upward and downward movements of

[1] This may be made the subject of a protracted class-room experiment. Strong shoots of willow should be used for the purpose.

sap there must be local transfers laterally through the stem, and these are at times of much importance to the plant.

93. *Rate of Movement of Water in the Stem.* — There are many practical difficulties in the way of ascertaining exactly how fast the watery sap travels from the root to the leaves. It is, however, easy to illustrate experimentally the fact that it does rise, and to give an approximate idea of the time required for its ascent. The best experiment for beginners is one which deals with an entire plant under natural conditions.

94. *Experiment 19.* *Wilting and Recovery.* — Allow a fuchsia or a hydrangea[1] which is growing in a flower-pot to wilt considerably for lack of watering. Then water it freely and record the time required for the leaves to begin to recover their natural appearance and position, and the time fully to recover.

The former interval of time will give a very rough idea of the time of transfer of water through the roots and the stem of the plant. From this, by measuring the approximate distance traveled, a calculation could be made of the number of inches per minute which water travels in this particular kind of plant, through a route which is partly roots, partly stem, and partly petiole. Still another method is to treat leafy stems as the student in Exp. 18 treated the twigs which he was examining, and note carefully the rate of ascent of the coloring liquid. This plan is likely to give results that are too low, still it is of some use. It has given results varying from 34 inches per hour for the willow to 880 inches per hour for the sunflower. A better method is to introduce the roots of the plant which is being experimented upon into a weak solution of some chemical substance which is harmless to the plant and which can readily be detected anywhere in the tissues of the plant by chemical tests. Proper tests are then applied to portions of the stem which are cut from the plant at short intervals of time.

[1] *Hydrangea hortensis.*

Compounds of the metal lithium are well adapted for use in this mode of experimentation.

95. *Causes of Movements of Water in the Stem.* — Some of the phenomena of osmose were explained in §§ 50–54, and the work of the root-hairs was described as due to osmotic action.

Root pressure (§ 55), being apparently able to sustain a column of water only 80 or 90 feet high at the most, and usually less than half this amount, would be quite insufficient to raise the sap to the tops of the tallest trees, since many kinds grow to a height of more than a hundred feet. Our Californian "big trees," or Sequoias, reach the height of over 300 feet, and an Australian species of Eucalyptus, it is said, sometimes towers up to 470 feet. Root pressure, then, may serve to start the soil-water on its upward journey, but some other force or forces must step in to carry it the rest of the way. What these other forces are is still a matter of discussion among botanists.

The slower inward and downward movement of the sap may be explained as due to osmose.

For instance, in the case of growing wood-cells, sugary sap from the leaves gives up part of its sugar to form the cellulose of which the wood-cells are being made.

This loss of sugar would cause a flow of rather watery sap to take place more rapidly than usual from the growing wood to the leaves, while at the same time a slow transfer of the dissolved sugar will be set up from leaves to wood. The water, as fast as it reaches the leaves, will be thrown off in the form of vapor, so that they will not become distended with water, while the sugar will be changed into cellulose and built into new wood-cells as fast as it reaches the region where such cells are being formed.

Plants in general[1] readily change starch to sugar, and sugar

[1] Not including most of the flowerless and very low and simple kinds.

to starch. When they are depositing starch in any part of the root or stem for future use, the withdrawal of sugar from those portions of the sap which contain it most abundantly gives rise to a slow movement of dissolved particles of sugar in the direction of the region where starch is being laid up.

96. *Storage of Food in the Stem.* — The reason why the plant may profit by laying up a food supply somewhere inside its tissues has already been suggested, § 70.

The most remarkable instance of storage of food in the stem is probably that of sago-palms, which contain an enormous amount, sometimes as much as 800 pounds, of starchy material in a single trunk. But the commoner plants of temperate regions furnish plenty of examples of deposits of food in the stem. As in the case of seeds and roots, starch constitutes one of the most important kinds of this reserve material of the stem, and since it is easier to detect than any other substance which the plant employs for this purpose, the student will do well to spend the time which he devotes to the study of storage of food in the stem to looking for starch only.

Cut thin cross-sections of twigs of any common hard-wood tree, in its winter condition, moisten with iodine solution, and examine for starch with a moderately high power of the microscope. Sketch the section, and describe exactly in what portions the starch is deposited.

97. *Storage in Underground Stems.* — The branches and trunk of a tree furnish the most convenient place in which to deposit nourishment during winter to begin the growth of the following spring. But in those plants which die down to the ground at the beginning of winter the storage must be either in the roots, as has been described in § 46, or in underground portions of the stem.

Rootstocks, tubers, and bulbs seem to have been developed by plants to answer as storehouses through the winter (or in

countries where there is one, through the dry season) for the reserve materials which the plant has accumulated during the growing season. The commonest tuber is the potato, and this fact and the points of interest which it represents make it especially desirable to use for a study of the underground stem in a form most highly specialized for the storage of starch and other valuable products.

98. *A Typical Tuber; the Potato.* — Sketch the general outline of a potato, showing the attachment to the stem from which it grew.[1]

Note the distribution of the "eyes," — are they opposite or alternate? Examine them closely with the magnifying glass and then with the lowest power of the microscope. What do they appear to be?

If the potato is a stem it may branch, — look over a lot of potatoes to try to find a branching specimen. If such a one is secured, sketch it.

Note the little scale overhanging the edge of the eye, and see if you can make out what this scale represents.

Cut the potato across, and notice the faint line which forms a sort of oval figure some distance inside the skin.

Place the cut surface in red ink, allow the potato to stand so for many hours, and then examine, by slicing off pieces parallel to the cut surface, to see how far and into what portions the red ink has penetrated. Refer to the notes on the study of the parsnip (§ 45), and see how far the behavior of the potato treated with red ink agrees with that of the parsnip so treated.

Cut a thin section at right angles to the skin, and examine with a high power. Moisten the section with iodine solution and examine again.

Make a cross-section and a lengthwise section through the stained ring from the piece left standing in red ink, and examine first with a low, then with a high power.

If possible secure a potato which has been sprouting in a warm place for a month or more (the longer the better), and look for evidences of the loss of material from the tuber.

99. *Experiment 20. Use of the Corky Layer.* — Carefully weigh a potato, then pare another larger one and cut portions from it until its weight is made approximately equal to that of the first one. Expose both freely to the air for some days and re-weigh. What does the result show in regard to the use of the corky layer of the skin?

[1] Examination of a lot of potatoes will usually discover specimens with an inch or more of attached stem.

100. *Morphology of the Potato.* — It is evident that in the potato we have to do with a very greatly modified form of stem. The corky layer of the bark is well represented, and the loose cellular layer beneath is very greatly developed; wood is almost lacking, being present only in the very narrow ring which was stained by the red ink, but the pith is greatly developed and constitutes the principal bulk of the tuber. All this is readily understood if we consider that the tuber, buried in and supported by the earth, does not need the kinds of tissue which give strength, but only those which are well adapted to store the requisite amount of nourishment.

101. *Structure of a Bulb; the Onion.*[1] — Examine the external appearance of the onion and observe the thin membranaceous skin which covers it. This skin consists of the broad sheathing bases of the outer leaves which grew on the onion plant during the summer. Remove these and notice the thick scales (also formed from bases of leaves as shown in Fig. 37) which make up the substance of the bulb.

Make a transverse section of the onion at about the middle and sketch the rings of which it is composed. Cut a thin section from the interior of the bulb, examine with a moderate power of the microscope, and note the thin-walled cells of which it is composed.

Split another onion from top to bottom and try to make out:

(*a*) The *plate* or broad flattened stem inside at the base, Fig. 36 *a*;

(*b*) The central bud;

(*c*) The bulb-scales;

(*d*) In some onions (particularly large, irregular ones) the bulblets or side buds arising in the axes of the scales near the base, Fig. 36 *b*.

Test the cut surface for starch.

Since the onion grows so rapidly on being planted in the spring there must be a large supply of nutritive material in the bulb. Much of this is in the form of *proteid* material. The proteids (§ 35) constitute a class of animal and vegetable substances, very valuable for food, of which the whites

[1] Probably a bulb with narrow scales like those of the lilies would be a more interesting form for study, but the onion is always and everywhere obtainable.

of eggs and the sticky part of dough made from wheat flour are good examples.

Nitric acid turns proteids yellow, and the addition of ammonia afterwards turns them deeper yellow or orange. As few other substances are affected in this way by nitric acid, this change of color is a very good test to show the presence of proteids.

102. ***Experiment 21.**** *Testing an Onion for Proteids.* — Test a rather thick slice of onion by heating it in a porcelain evaporating dish with a little strong nitric acid until the latter begins to boil and the onion becomes somewhat softened.[1] Rinse off the slice of onion in a stream of water, then pour on it a few drops of ammonia water and observe what changes of color (if any) occur.

Grape sugar is an important substance among those stored for food by the plant. It received its name from the fact that it was formerly obtained for chemical examination from grapes. Old dry raisins usually show little masses of whitish material scattered over the skin which are nearly pure grape sugar. Commercially it is now manufactured on an enormous scale from starch by boiling with diluted sulphuric acid. In the plant it is made from starch by processes as yet imperfectly understood, and another sugar, called *maltose*, is made from starch in the seed during germination.

Both grape sugar and maltose (and hardly any other substances) have the power of producing a yellow or orange color and throwing down an orange or reddish deposit, when they are added to a brilliant blue alkaline solution of copper, known as *Fehling's solution.*[2] The color or deposit will not appear until the solution has been heated to boiling.

[1] Do not allow the acid to touch the hands, the clothing, or any metallic object.

If it is desirable to show the result of the test to one or more classes, the portion of the onion stained yellow by the acid may be placed in a small wide-mouthed bottle with ground stopper, in which it may be kept for a long time and conveniently passed from hand to hand.

[2] For the preparation of the solution see Appendix B.

103. ***Experiment 22.*** *Testing for Grape Sugar.* — Heat to boiling in a test-tube or a small beaker some weak syrup of grape sugar or some honey, much diluted with water. Add Fehling's solution, a few drops at a time, until a decided orange color appears. Repeat the test with the water in which some slices of onion have been boiled, filtering the water through a paper filter and heating again to boiling before adding the test solution.[1]

Does the onion contain grape sugar?

[1] The deposit will in this case, even if orange at first, finally become black, probably owing to the presence of sulphur in the onion.

CHAPTER VIII.

Buds.

104. *Structure of Buds.* — While studying twigs in their winter condition, as directed in §§ 58, 59, the student had occasion to notice the presence, position, and arrangement of buds on the branch, but he was not called upon to look into the details of their structure. The most natural time to do this is just before the study of the leaf is begun, since, as every one knows, leaves spring from buds and the rudiments of leaves in some form must be found there.

105. *The Horse-Chestnut Bud.* — Examine one of the lateral buds on a twig in its winter or early spring condition.[1]

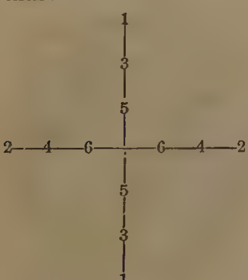
Make a sketch of the external appearance of the buds as seen with a magnifying glass.

The scales with which it is covered will be seen to overlap each other like shingles on a roof, and the thin edges of the scales fit very closely down over those beneath.

Notice the sticky coating on the scales.

Are the scales opposite or alternate?

Remove the scales in pairs, placing them in order on a sheet of paper, thus:



Make the distance from 1 to 1 as much as 6 or 8 inches.

How many pairs are found?

Observe as the scales are removed whether the sticky coating is thicker on the outside or the inside of each scale, and whether it is equally abundant on all the successive pairs.

What is the probable use of this coating?

Note the delicate veining of some of the scales as seen through the magnifying glass.

[1] The best possible time for this examination is just as the buds are beginning to swell slightly in the spring. The buckeye will do for this examination, though it is on a good deal smaller scale than the horse-chestnut. Buds may be forced to open early by standing twigs in water in a very warm, light place.

Describe the texture, thickness, transparency, color, and so on, of each pair of scales.

Inside the innermost pair are found two forked woolly objects; what are these?

Compare with Fig. 75.

Their shape could be more readily made out if the woolly coating were removed.

Try the effect of immersing the inner portion of the bud for a few minutes in strong sulphuric acid to dissolve and remove the down, so as to show the parts more plainly.[1]

Can you suggest a use for the woolly coating?

FIG. 56. — Transition from Bud-Scales to Leaves in the Common Currant.

Examine a terminal bud in the same way in which you have just studied the lateral bud.

Does it contain any parts not found in the other?

What is the appearance of these parts?

What do they represent?

If there is any doubt about their nature, study them further on a horse-chestnut tree during and immediately after the process of leafing out in the spring.

For comparison study at least one of the following kinds of buds in their winter or early spring condition: Hickory, butternut, beech, ash, magnolia (or tulip tree), lilac, balm of Gilead, cultivated cherry.[2]

106. *Nature of Bud-Scales.* — The fact that the bud-scales are in certain cases merely imperfectly developed leaves is often clearly manifest from the series of steps connecting the bud-scale on the one hand with the young leaf on the other, which may be found in many opening buds, as illustrated by Fig. 56. In other buds the scales are not imperfect leaves, but the little appendages (*stipules*, § 117) which occur at the

[1] The acid must not be allowed to get on the hands, the table, or the clothes, or it will cause much trouble. Remove it by rinsing in plenty of water.

[2] Consult the account of the mode of studying buds in Miss Newell's *Outlines*, Part I. If some of the buds are studied at home, pupils will have a better chance to examine at leisure the unfolding process.

bases of leaves. This kind of bud-scale is especially well shown in the magnolia and the tulip tree.

107. *Naked Buds.* — All of the buds above-mentioned are *winter buds*, capable of living through the colder months of the year, and are scaly buds.

In the herbs of temperate climates, and even in shrubs and trees of tropical regions, the buds are often *naked*, that is nearly or quite destitute of scaly coverings.

Make a study of the naked buds of any convenient herb, such as one of the common "geraniums" (pelargonium), and record what you find in it.

108. *Position of Buds.* — The distinction between *lateral* and *terminal* buds has already been alluded to.

The plumule is the first terminal bud which the plant produces. Lateral buds are usually *axillary*, as shown in Fig. 57. But not infrequently there are several buds grouped in some way about a single leaf-axil, either one above the other, as in the black walnut, Fig. 58, or grouped side by side, as in the red maple and the cherry, Fig. 59.

FIG. 57. — Alternate Leaves of Cultivated Cherry, with Buds in their Axils, in October.

In these cases all the buds except the axillary one are called *accessory* or *supernumerary* buds.

109. *Leaf-Buds and Flower-Buds; the Bud an Undeveloped Branch.* — Such buds as the student has so far examined for

himself are not large enough to show in the most obvious way the relation of the parts and their real nature.

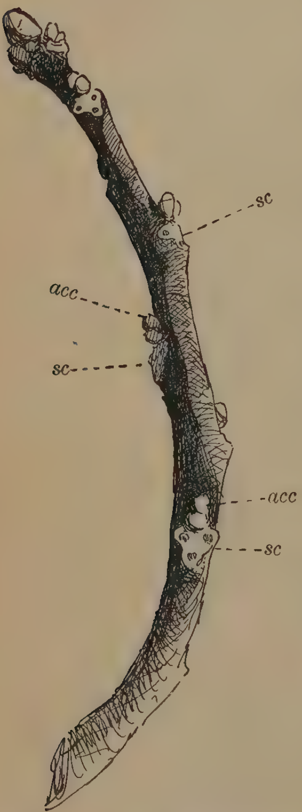


FIG. 58.—A Twig of Black Walnut. *sc*, scar left by fallen leaf; just above this is an ordinary bud, and still higher up, *acc*, an accessory bud.

Fortunately, it is easy to obtain a gigantic bud which illustrates perfectly the structure and arrangement of buds in general.

Examine and sketch a cabbage which has been split lengthwise through the centre[1] and note

(*a*) The short, thick, conical stem.

(*b*) The crowded leaves which arise from the stem, the lower and outer ones largest and most mature, the upper and innermost ones the smallest of the series.

Compare the section of the cabbage with Fig. 60.

Most of the buds so far considered are *leaf-buds*, that is, their inner parts will develop into leaves, and their central axes into stems; but some were *mixed buds*, that is, they contained both leaves and flowers in an undeveloped condition.

Flower-buds contain the rudiments of flowers only.

Sometimes, as in the black walnut, the leaf-buds and flower-buds are readily distinguishable by their difference in form, while in other cases, as in the cultivated cherry, the difference in form is but slight.

[1] Half of a cabbage will be enough for the entire division.

The rings of scars about the twig, shown in Figs. 23 and 59, mark the place where the bases of bud-scales were attached. A little examination of the part of the twig which lies outside of this ring, as shown in Fig. 23, will lead one to the conclusion that this portion has all grown in the one spring and summer since the bud-scales of that particular ring dropped off. Following out this suggestion, it is easy to reckon the age of any moderately old portion of a branch, since it is equal to the number of segments between the rings. In rapidly growing shoots of willow, poplar, and similar trees, five or ten feet of the length may be the growth of a single year, while in the lateral twigs of the hickory, apple, or cherry the yearly increase may be but a fraction of an inch. Whatever the amount of this

FIG. 59. — A Slowly grown Twig of Cherry, three inches long and about ten years old.

The more pointed terminal bud is a leaf-bud, the more obtuse accessory buds, *acc*, are flower-buds.

FIG. 60. — I, a Twig of European Elm. II, a Longitudinal Section of the Buds of I, considerably magnified.

a, the axis of the bud, which will elongate into a shoot; *b*, leaf-scars.

growth, it is but the lengthening out and development of the bud, which may be regarded as an undeveloped stem or branch, with its internodes so shortened that successive leaves seem almost to spring from the same point.

110. *Vernation.* — Procure a considerable number of buds which are just about to burst, and others which have begun to open. Cut each across with a razor or very sharp scalpel; examine first with the magnifying glass, and then with the lowest power of the microscope. Pick to pieces other buds of the same kinds under the magnifying glass, and report upon the manner in which the leaves are packed away.

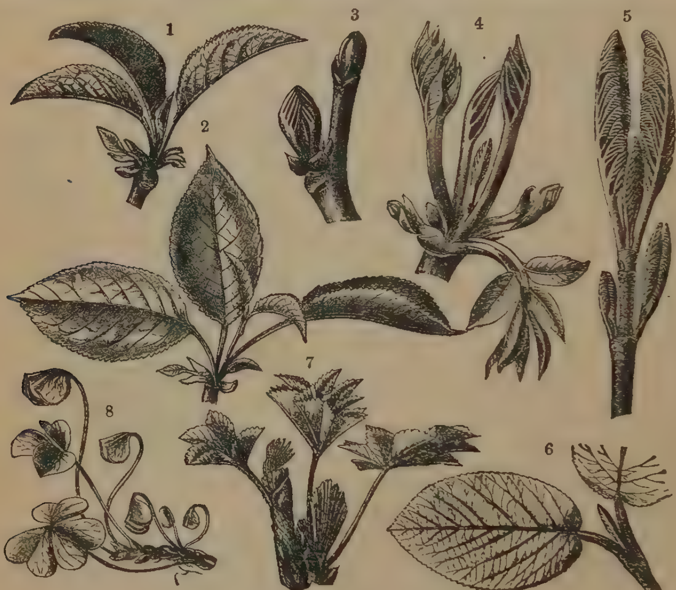


FIG. 61. — Types of Vernation.
1, 2, cherry; 3, 4, European walnut; 5, 6, snowball; 7, lady's-mantle; 8, wood sorrel.

The arrangement of leaves in the bud is called *vernation;* some of the principal modes are shown in Fig. 61. In the cherry the two halves of the leaf are folded together flat, with

the under surfaces outward; in the walnut the separate *leaflets*, or parts of the leaf, are folded flat and then grouped into a sort of cone; in the snowball each half of the leaf is plaited in a somewhat fan-like manner, and the edges of the two halves are then brought round so as to meet; in the lady's-mantle the fan-like plaiting is very distinct; in the wood sorrel each leaflet is folded smoothly, and then the three leaflets packed closely side by side. All these modes of vernation and many others have received accurate descriptive names by which they are known to botanists.

111. *Importance of Vernation.*—The significance of vernation is best understood by considering that there are two important purposes to be served; the leaves must be stowed as closely as possible in the bud, and upon beginning to open they must be protected from too great heat and dryness until they have reached a certain degree of firmness. It may be inferred from Fig. 61 that it is common for very young leaves to stand vertically. This protects them considerably from the scorching effect of the sun at the hottest part of the day. Many young leaves, as for instance those of the silver-leafed poplar, the pear, the beech, and the mountain ash, are sheltered and protected from the attacks of small insects by a coating of wool or down, which they afterwards lose. Those of the tulip tree are enclosed for a little time in a thin pouch, formed from the bud-scales,[1] and thus entirely shielded from direct contact with the outside air.

112. *Dormant Buds.*—Generally some of the buds on a branch remain undeveloped in the spring, when the other buds are beginning to grow, and this inactive condition may last for many seasons. Finally the bud may die, or some injury to the tree may destroy so many other buds as to leave the dormant ones an extra supply of nourishment, and this, with other causes, may force them to develop and to grow into branches.

[1] These are in this case stipules, § 117.

Sometimes the tree fails altogether to produce buds at places where they would regularly occur. In the lilac the terminal bud usually fails to appear, and the result is constant forking of the branches.

113. *Adventitious Buds.*—Buds which occur in irregular places, that is, not terminal nor in or near the axils of leaves, are called *adventitious buds;* they may spring from the roots, as in the silver-leafed poplar, or from the sides of the trunk, as in our American elm. In many trees, for instance willows and maples, they are sure to appear after the trees have been cut back. Willows are thus cut back or *pollarded,* as shown in Fig. 62, in order to cause them to produce a large crop of slender twigs suitable for basket-making.


FIG. 62.—Branches formed from Adventitious Buds on Pollarded Willows.

Leaves rarely produce buds, but a few kinds do so when they are injured; and those of the bryophyllum, a plant allied to the garden live-for-ever, almost always send out buds from the margin when they are removed from the plant while they are still green and fresh.

114. *Experiment 23.*—Pin up a bryophyllum leaf on the wall of the room or lay it on the surface of moist earth, and follow, day by day, the formation and development of the buds which it may produce.

This plant seems to rely largely upon leaf-budding to reproduce itself, for in a moderately cool climate it rarely flowers or seeds, but drops its living leaves freely, and from each such leaf one or several new plants may be produced.

CHAPTER IX.

Leaves.

115. *The Elm Leaf.* — Sketch the leafy twig of elm that is supplied to you.[1]

Report on the following points :

(*a*) How many rows of leaves ?

(*b*) How much overlapping of leaves when the twig is held with the upper sides of the leaves toward you ? Can you suggest a reason for

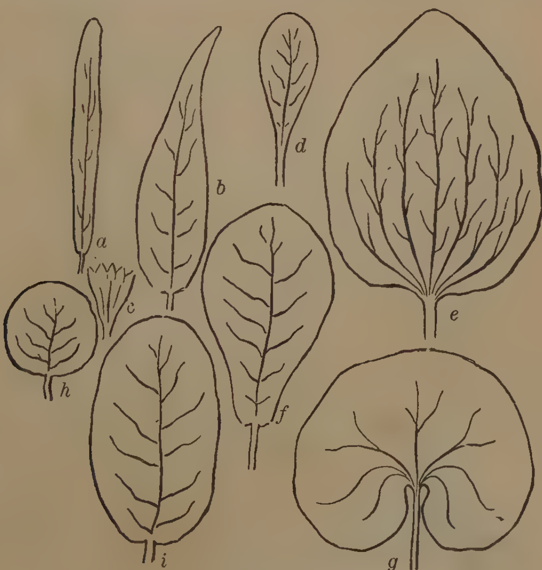


FIG. 63. — General Outline of Leaves.

a, linear ; *b*, lanceolate ; *c*, wedge-shaped ; *d*, spatulate ; *e*, ovate ; *f*, obovate ; *g*, kidney-shaped ; *h*, orbicular ; *i*, elliptical.

[1] Any elm will answer th purpose. Young strong shoots which extend horizontally are best, since in these leaves are most fully developed and their distribution along the twig appears most clearly. Other good kinds of leaves with which tò begin the study, if elm leaves are not available, are those of beech, oak, willow, peach,

this? Are the spaces between the edges of the leaves large or small compared with the leaves themselves?

Pull off a single leaf and make a very careful sketch of its under surface, about natural size. Label the broad expanded part the *blade*, and the stalk by which it is attached to the twig, leaf-stalk or *petiole*.

Study the outline of the leaf and answer these questions:

(*a*) What is the shape of the leaf, taken as a whole? (See Fig. 63.) Is the leaf *bilaterally symmetrical*, *i.e.*, is there a middle line running

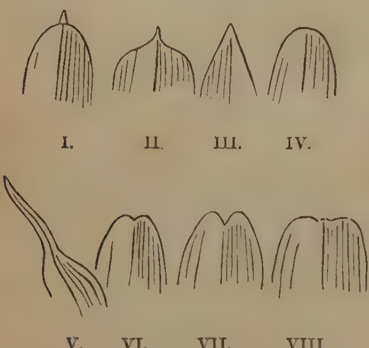


FIG. 64. — Shapes of Tip of Leaf.

I, mucronate, the midrib prolonged into a hard short point; II, cuspidate, tapering into a stiff point; III, acute; IV, rounded;[1] V, acuminate or taper-pointed; VI, retuse, with the rounded end slightly notched; VII, emarginate, deeply notched; VIII, truncate, with the end cut off rather squarely.

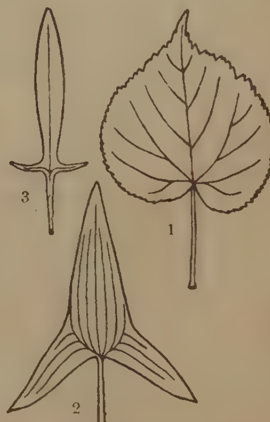


FIG. 65. — Shapes of Bases of Leaves.

1, heart-shaped (unsymmetrically); 2, arrow-shaped; 3, halberd-shaped.

through it lengthwise, along which it could be so folded that the two sides would precisely coincide?

(*b*) What is the shape of the tip of the leaf? (See Fig. 64.)

(*c*) Shape of the base of the leaf. (See Fig. 65.)

(*d*) Outline of the margin of the leaf? (See Fig. 66.)

cherry, apple. Most of the statements and directions above given would apply to any of the leaves just enumerated. If this chapter is reached too early in the season to admit of suitable material being procured for the study of leaf arrangement, that topic may be omitted until the leaves of forest trees have sufficiently matured.

[1] Any form intermediate between III and IV would be called obtuse.

Notice that the leaf is traversed lengthwise by a strong *midrib* and that many so-called *veins* run from this to the margin. Are these veins parallel? Hold the leaf up toward the light and see how the main veins are connected by smaller *veinlets*. Examine with your glass the leaf as held to the light and make a careful sketch of portions of one or two veins and the intersecting veinlets. How is the course of the veins shown on the upper surface of the leaf?

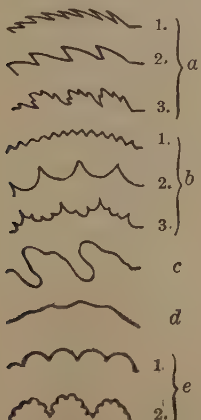


FIG. 66.—Shapes of Margins of Leaves. *a* (1), finely serrate; (2), coarsely serrate; (3), doubly serrate. *b* (1), finely dentate; (2), sinuate dentate; (3), doubly dentate. *c*, deeply sinuate. *d*. wavy. *e* (1), crenate or scalloped; (2), doubly crenate.

FIG. 67.—Netted Veining (pinnate) in the Leaf of the Foxglove.

Examine both surfaces of the leaf with the glass and look for hairs distributed on the surfaces. Describe the manner in which the hairs are arranged.

The various forms of leaves are classed and described by botanists with great minuteness,[1] not simply for the study of

[1] See Kerner and Oliver's *Natural History of Plants*, vol. I, pp. 623–637.

leaves themselves, but also because in classifying and describing plants the characteristic forms of the leaves of many kinds of plants form a very simple and ready means of distinguishing them from each other and identifying them. The student is not expected to learn the names of the several shapes of leaves as a whole or of their bases, tips, or margins, except in those cases in which he needs to use and apply them.

116. *The Maple Leaf.*[1] — Sketch the leafy twig.

Are the leaves arranged in rows like those of the elm? How are they arranged?

FIG. 68. — Palmately Netted-Veined Leaf of Melon.

FIG. 69. — Pinnately Divided Leaf of Celandine.

The blade of the leaf is discontinuous, consisting of several portions between which are spaces in which no part of the blade has been developed.

Notice the way in which half of the whole number of petioles are twisted and some of the others bent to bring the proper surface of the leaf upward toward the light.

Do the edges of these leaves show larger spaces between them than the elm leaves did, *i.e.*, would a spray of maple intercept the sunlight

[1] Any kind of maple will answer the purpose. Palmately veined leaves are less abundant among our forest trees than are pinnately veined ones. The sycamore is one of the commonest species. Among other plants may be suggested the ordinary "geraniums" (pelargoniums), the pumpkin, squash, grape, currant, and hollyhock.

more or less perfectly than a spray of elm? Pull off a single leaf and sketch its lower surface, about natural size.

Of the two main parts whose names have already been learned (blade and petiole), which is more developed in the maple than in the elm leaf?

Describe:

(*a*) The shape of the maple leaf as a whole.

(*b*) Its outline as to main divisions, of what kind and how many.

(*c*) The detailed outline of the margin (Fig. 66).

Compare the mode of veining or venation of the elm and the maple leaf by making a diagram of each.

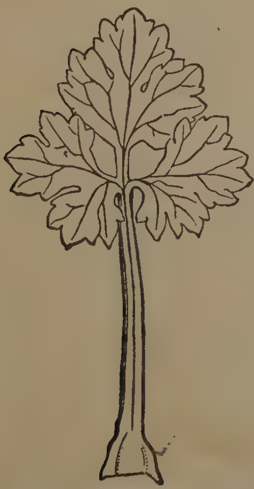


FIG. 70. — Palmately Divided Leaf of Buttercup.

FIG. 71. — Leaf of Apple, with Stipules.

FIG. 72.—Leaf of Pansy, with Leaf-like Stipules.

They agree in being *netted-veined*, *i.e.*, in having veinlets that join each other at many angles so as to form a sort of delicate lace-work like Figs. 67, 68.

They differ, however, in the arrangement of the principal veins. Such a leaf as that of the elm is said to be feather-veined, or *pinnately veined*.

The maple leaf, or any leaf with closely similar venation, is said to be *palmately veined*. Describe the difference between the two plans.

117. *Stipules.* — Although they are absent from many leaves, and disappear early from others, *stipules* form a part of what the botanist regards as an ideal or model leaf.[1] When present they are sometimes found as little bristle-shaped objects, at the base of the leaf as in the apple leaf (Fig. 71), sometimes as leaf-like bodies, for example in the pansy (Fig. 72), and in many other forms, one of which is that of spinous appendages, as shown in the common locust (Fig. 76).

118. *Relation of Venation to Shape of Leaves.* — As soon as the student begins to observe leaves somewhat widely, he can hardly fail to notice that there is a general relation between the plan of venation and the shape of the leaf. How may this relation be stated? In most cases the principal veins follow at the outset a pretty straight course, a fact for which the student ought to be able to give a reason after he has performed Exp. 25.

FIG. 73. — Parallel-Veined Leaf of Solomon's Seal.

On the whole the arrangement of the veins seems to be such as to stiffen the leaf most in the parts that need most support, and to reach the region near the margin by as short a course as possible from the end of the petiole.

119. *Parallel-Veined Leaves.* — The leaves of many great groups of plants, such as the lilies, the sedges, and the grasses, are commonly *parallel-veined*, that is, with the veins running nearly parallel, lengthwise through the blade, as shown in Fig. 73, or with parallel veins proceeding from a midrib and then sending off parallel veinlets, as shown in Fig. 74.

[1] Unless the elm twigs used in the previous study were cut soon after the unfolding of the leaves in spring, the stipules may not have been left in any recognizable shape.

120. *Occurrence of Netted Veining and of Parallel Veining.* —The student has already, in his experiments on germination, had an opportunity to observe the difference in mode of veining between the leaves of some dicotyledonous plants and those of monocotyledonous plants. This difference is general throughout these great groups of flowering plants. What is the difference?

The polycotyledonous pines, spruces, and other coniferous trees have leaves with but a single vein, or two or three parallel ones, but in their case the veining could hardly be other than parallel, since the needle-like leaves are so narrow that no veins of any considerable length could exist except in a position lengthwise of the leaf.

FIG. 74. — Parallel Veining in Canna. Veins running from midrib to margin.

The fact that a certain plan of venation is found mainly in plants with a particular mode of germination, of stem structure, and of arrangement of floral parts, is but one of the frequent cases in botany in which the structures of plants are correlated in a way which it is not easy to explain.

No one knows why plants with two cotyledons should have netted-veined leaves, but many such facts as this are familiar to every botanist.

121. *Simple and Compound Leaves.*—The leaves so far studied are *simple leaves*, that is, leaves of which the blades are more or less entirely united into one piece. But while in the elm the margin is cut in only a little way, in some maples it is deeply cut in toward the bases of the veins. In some leaves the gaps between the adjacent portions extend all the way down to the petiole (in palmately veined leaves) or to

the midrib (in pinnately veined ones). Such divided leaves are shown in Figs. 69 and 70.

In still other leaves, known as *compound leaves,* the petiole, as shown in Fig. 75, or the midrib, as shown in Fig. 76, bears what look to be separate leaves. These differ in their nature and mode of origin from the portions of the blade of a divided leaf. One result of this difference appears in the fact

FIG. 75. — The Fall of the Horse-Chestnut Leaf.

that some time before the whole leaf is ready to fall from the tree or other plant in autumn, the separate portions or leaflets of a compound leaf are seen to be jointed at their attachments, just as whole leaves are to the part of the stem from which they grow. In Fig. 75 the horse-chestnut leaf is shown at the time of falling, with some of the leaflets already disjointed.

That a compound leaf, in spite of the joints of the separate leaflets, is really only one leaf, is shown: (1) by the absence of buds in the axils of leaflets; (2) by the arrangement of the blades of the leaflets horizontally, without any twist in their individual leafstalks; (3) by the fact that their arrangement

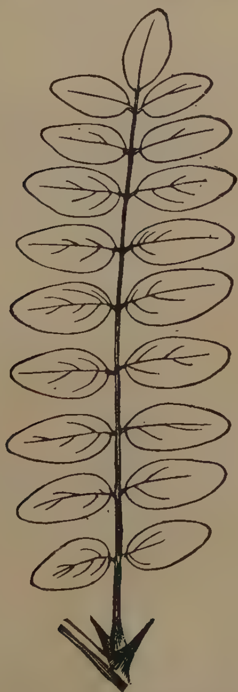


FIG. 76. — Pinnately Compound Leaf of Locust, with Spines for Stipules.

on the midrib does not follow any of the systems of leaf arrangement on the stem (§ 122). If each leaflet of a compound leaf should itself become compound, the result would be to produce a *twice compound* leaf. Fig. 85 shows that of an acacia.

CHAPTER X.

Leaf Arrangement for Exposure to Sun and Air; Movements of Leaves and Shoots.

122. *Leaf Arrangement.*[1] — As has been learned from the study of the leafy twigs examined, leaves are quite generally arranged so as to secure the best possible exposure to the sun and air. This,

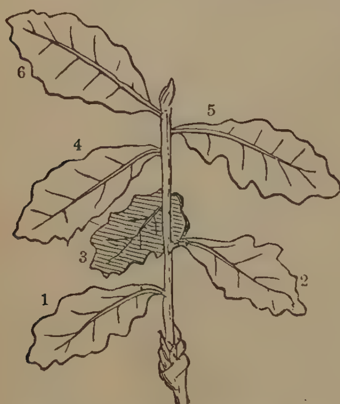


FIG. 77. — Leaf Arrangement of the Oak.

FIG. 78. — Leaf Arrangement of European Beech.

in the vertical shoots of the elm, the oak (Fig. 77), the apple, beech, and other alternate-leaved trees, is not inconsistent with their spiral arrangement of the leaves around the stem. In horizontal twigs and branches of the elm, the beech (Fig. 78), the chestnut, the linden, and many other trees and shrubs, the desired effect is secured by the arrangement of all the leaves in two flat rows, one on each side of the twig. The rows are produced, as it is easy to see on examining such a

[1] See Kerner and Oliver's *Natural History of Plants*, vol. I, pp. 396–424

leafy twig, by a twisting about of the petioles. The adjustment in the syringa, the maple, the horse-chestnut (Fig. 79),

FIG. 79.—Leaf Arrangement of Horse-Chestnut on Vertical Shoots (top view).

FIG. 80.—Leaf Arrangement of Horse-Chestnut on Vertical Shoots (side view).

and many other opposite-leaved trees and shrubs, consists in having each pair of leaves cover the spaces between the

pair below it, and sometimes in the lengthening of the lower petioles so as to bring the blades of the lower leaves outside those of the upper leaves. Examination of Fig. 80 will make the matter clear.

The student should not fail to study the leafage of several trees of different kinds on the growing tree itself, and to

FIG. 81. — Opposite Leaves of Deutzia [1] (from the same shrub as Fig. 82), as arranged on horizontal branch.

notice how circumstances modify the position of the leaves. Maple leaves, for example, on the ends of the branches are arranged much like those of the horse-chestnut, but they are found to be arranged more nearly flatwise along the inner portions of the branches, that is, the portions nearer the tree.

[1] *Deutzia crenata.*

Figs. 81 and 82 show the remarkable difference in arrangement in different branches of the Deutzia, and equally interesting

FIG. 82. — Opposite Leaves of Deutzia, as arranged on a vertical branch.

FIG. 83. — Leaves of Castor-Oil Plant, seen from above, showing exposure to sunlight. (Much reduced.)

modifications may be found in alternate-leaved trees, such as the elm and the cherry.

Where the stem on which the leaves are borne stands neither horizontally nor vertically, but at some oblique angle to the earth's surface, the leaf arrangement is more or less irregular, as in Fig. 83, which represents the leafage of a castor-oil plant growing in an inclined position, because it was shaded on one side.

123. *Daily Movements of Leaves.* — Many compound leaves have the power of changing the position of their leaflets to accommodate themselves to varying conditions of light and temperature. The so-called "sleep" of plants has long been known, but this subject has been most carefully studied rather recently. The wood sorrel, or oxalis, the common bean, clovers, and the locust tree are some of the most familiar of the plants whose leaves assume decidedly different positions at night from those which they occupy during the day. Sometimes the leaflets rise at night, and in many instances they droop, as in the white clover, Fig. 84, and the acacia, Fig. 85. One useful purpose, at any rate, that is served by the leaf's taking the nocturnal position is protection from frost. It has been proved experimentally that when part of the leaves on a plant are prevented from assuming the folded position, while others are allowed to do so, and the plant is then exposed during a frosty night, the folded ones may escape while the others are killed. The student may very naturally inquire whether the change to the nocturnal position is brought about by the change from light to darkness or whether it depends rather upon the time of day. It will be interesting to try an experiment in regard to this.

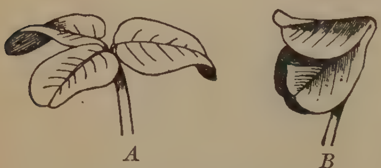


FIG. 84. — A Leaf of White Clover.
A, leaf by day ; *B*, the same leaf asleep at night.

124. ***Experiment 24.*** — Remove a pot containing an oxalis from a sunny window to a dark closet, and note at intervals of five minutes the condition of its leaves for half an hour or less.

Some plants have the power of directing the leaves edgewise towards the sun during the hottest parts of the day, allowing them to extend their surfaces more nearly in a horizontal direction during the cooler hours.

A *B*

FIG. 85. — A Leaf of Acacia.
A, as seen by day; *B*, the same leaf asleep at night.

125. *Vertically Placed Leaves.* — Very many leaves, like those of the iris, Fig. 34, always keep their principal surfaces nearly vertical, thus receiving the morning and evening sun upon their faces, and the noonday sun (which is so intense as to injure them when received full on the surface) upon their edges. This adjustment is most perfect in the compass-plant of the prairies of the Mississippi basin. Its leaves stand very

nearly upright, with their edges approximately north and south, Fig. 86, so that the rays of the midsummer sun will during every bright day first strike the leaf-surfaces at right

FIG. 86. — Leaves standing nearly Vertical in Compass-Plant (*Silphium laciniatum*).

angles, then be nearly parallel to them, and again toward sunset strike them at right angles.

126. *Movements of Leaves and Stems toward Light.* — The student doubtless learned from his experiments with seedling

plants that they tend to seek the light. The whole plant usually bends toward the quarter from which the strongest light comes, and the petioles bend with it. Such movements may produce very perceptible changes in the course of a few hours. If the position of the plant is shifted after the mature portions have taken a permanent bend, the youngest

FIG. 87.—Shoots of Dwarf Tropæolum, showing bending of young shoots toward sunlight.

The older portions of the shoots have bent to the left, away from the light (as climbing plants usually do), and toward a close fence. The younger tips of the shoots have bent to the right, the direction from which most light was received.

portions may be made to bend in the opposite direction, as shown in Fig. 87, and a third bending may then be produced, giving the longer shoots the form of the capital letter S.

It is not easy to explain in detail how the tissues of the plant act in producing these movements.

CHAPTER XI.

Leaves of Peculiar Forms and Uses.

127. *Leaves in Hot, Dry Climates.* — In regions where the greatest dangers to vegetation arise from long droughts and the excessive heat of the sun, the leaves of plants usually offer much less surface to the sun and air than is the case in temperate climates. Sometimes the blade is absent and the

FIG. 88. — Leaf of Nightshade,[1] with Midrib Prickly above and below.

FIG. 89. — Spiny Leaves of Barberry.

expanded petiole answers the purpose of a blade, or again, foliage leaves are lacking altogether, as in the cactuses (Fig. 38) and the euphorbias (Fig. 90), and the green outer layers of the stem do the work of the leaves.

[1] *Solanum.*

128. *Prickly Leaves.* — In many whole groups of plants the leaves are sufficiently prickly or spiny to serve the plant as a protection against browsing animals. Oftentimes the prickles are borne on the midrib or the principal veins only, as in some kinds of nightshade (Fig. 88). At other times the tip of the midrib, or the tips of that and other veins become spiny, as in the thistle. In many acacias, and in some euphor-

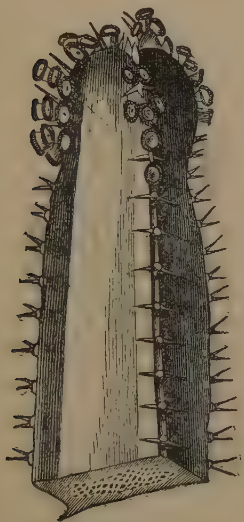


FIG. 90. — Branch of a Euphorbia, with Spiny Stipules.

FIG. 91. — Compound Leaf of Pea,[1] the leaflets at the upper end in the form and doing the work of tendrils.

bias (Fig. 90), the stipules form slender spines. Sometimes, in the barberry, for example, whole leaves become narrowed and hardened into spines. (Fig. 89.)

129. *Leaves as Aids to Climbing.* — Some pinnately compound leaves, like those of the pea, terminate in a tendril

[1] In young seedlings, as the student has already learned during the germination experiments, only one pair of leaflets will be found.

(Fig. 90), by means of which the plant is enabled to climb. Occasionally a tendril takes the place of the whole leaf, and again tendrils occupy the place of stipules. The long petioles of some leaves aid the plant to climb by twining themselves about any convenient support, as is the case with the common "nasturtium" (Tropæolum), Fig. 31.

130. *Leaves as Insect Traps.*—In the ordinary pitcher plants (Fig. 92), the leaf appears in the shape of a more or

FIG. 92.—Common Pitcher Plant.[1] At the right one of the pitcher-like leaves is shown in cross-section.

FIG. 93.—A Leaf of Sundew.[2] (Slightly magnified.)

less hooded pitcher. These pitchers are usually partly filled with water, and in this water very many drowned and decaying insects are commonly to be found. The insects have flown or crawled into the pitcher, and, once inside, have been unable to escape on account of the dense growth of bristly hairs about the mouth, all pointing inward and downward.

[1] *Sarracenia purpurea.* [2] *Drosera rotundifolia.*

How much the common American pitcher plants depend for nourishment on the drowned insects in the pitchers is not definitely known, but it is certain that some of the tropical species require such food.[1]

In other rather common plants, the sundews, insects are caught by a sticky secretion which proceeds from hairs on the leaves. In one of the commonest sundews the leaves consist of a roundish blade, borne on a moderately long petiole. On the inner surface and round the margin of the blade (Fig. 93) are borne a considerable number of short bristles, each terminating in a knob which is covered with a clear, sticky liquid. When a small insect touches one of the sticky knobs, he is held fast and the hairs at once begin to close over him, as shown in Fig. 94. Here he soon dies and then usually remains for many days, while the leaf pours out a juice by which the soluble parts of the insect are digested. The liquid containing the digested portions is then absorbed by the leaf and contributes an important part of the nourishment of the plant, while the undigested fragments, such as legs, wing-cases, and so on remain on the surface of the leaf or may drop off after the hairs let go their hold on the captive insect.

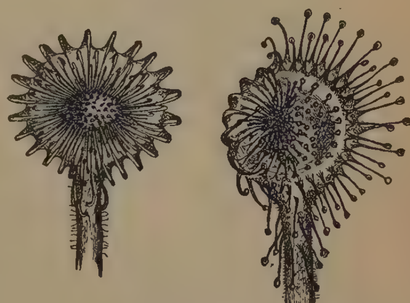


FIG. 94. — Leaves of Sundew. (Slightly magnified.)

The one at the left has all its tentacles closed over captured prey; the one at the right has only half of them thus closed.

[1] Where the *Sarracenia* is abundant it will be found interesting and profitable to make a careful class study of its leaves. See Geddes, *Chapters in Modern Botany*, Chapters I and II.

In the Venus' flytrap, which grows in the sandy regions of eastern North Carolina, the mechanism for catching insects is still more remarkable. The leaves, as shown in Fig. 95, terminate in a hinged portion which is surrounded by a fringe of stiff bristles. On the inside of each half of the trap grow three short hairs. The trap is so sensitive that when these hairs are touched it closes with a jerk and very generally succeeds in capturing the fly or other insect which has sprung it. The imprisoned insect then dies and is digested, somewhat as in the case of those caught by the sundew, after which the trap reopens and is ready for fresh captures.

FIG. 95. — Venus' Flytrap.

131. *Object of Catching Animal Food.* — It is easy to understand why a good many kinds of plants have taken to catching insects, or even (in the case of some of the large tropical pitcher plants) to catching birds, killing them, digesting them, and absorbing the digested products. Carnivorous, or flesh-eating, plants belong usually to one of two classes as regards their place of growth: they are bog-plants or air-plants. In either case their roots find it difficult to secure much nitrogen-containing food, that is, much food out of which proteid material can be built up. Animal food, being itself largely proteid, is admirably adapted to nourish the growing parts of

plants, and those which could develop insect-catching powers would stand a far better chance to exist as air-plants or in the thin, watery soil of bogs than plants which had acquired no such resources.

132. *Leaf Disguises.*—Leaves in the form of spines, of tendrils, and of pitchers have been referred to, and it is not uncommon to find leaves in other forms, hardly recognizable, except by the botanist, as leaves. The student has learned to consider bud-scales and the scales on root-stocks and bulbs as leaves (§§ 101, 106). Storage-leaves above ground are common in desert regions and not very unusual in plants of temperate climates. The common century plant is an excellent example of food-storage in the leaf, and the aloes, echeverias and house-leeks are other instances. There is little difficulty in recognizing dwarfed leaves in the little bracts which occur in many kinds of flower-cluster (Fig. 105). Scale-like leaves are found on some stems above ground, as in the case of the curious Indian pipe (Fig. 100), and on young shoots of asparagus in early spring. Leaves forming the parts of the flower will be studied in a later chapter (XVI). The leaf sometimes, though rarely, appears as a wing to aid in the transportation of the fruit, as in the linden (Fig. 173).

CHAPTER XII.

Minute Structure of Leaves; Functions of Leaves.

133. *Leaf of Lily.* — A good kind of leaf with which to begin the study of the microscopical structure of leaves in general is that of the lily.[1]

134. *Cross-Section of Lily Leaf.* — The student should first examine with the microscope a cross-section of the leaf, that is, a very thin slice, taken at right angles to the upper and under surfaces and to the veins. This will evidently show:

(*a*) The upper epidermis of the leaf.

(*b*) The intermediate tissues.

(*c*) The lower epidermis.

Use a power of from 100 to 200 diameters. In order to make out the relations of the parts, and to get their names, consult Fig. 96. Your section is by no means exactly like the figure. Label properly all the parts shown in your sketch.

Are any differences noticeable between the upper and the lower epidermis? Between the layers of cells immediately adjacent to each?

The teacher can (after considerable practice) prepare such sections by doubling the leaf crosswise once or twice, and then slicing the required sections from the end of the folded leaf, held firmly in the hand, if necessary between bits of elder-pith to hold it in position. The razor must be sharp, and the stroke made rather quickly and long.[2] The upper edge of a section may be distinguished from the under one by the presence in the former of *palisade* cells, so called from their resemblance to the high fence known as a palisade, made of stout stakes driven into the ground, Fig. 96. Mount in glycerine for temporary use in class.

135. *Under Surface of Lily Leaf.* — Examine with a power of 200 or more diameters the outer surface of a piece of epidermis from the lower side of the leaf.[3] Sketch carefully, comparing your sketch with Figs. 97 and 98, and labeling it to agree with those figures.

[1] Any kind of lily will answer.

[2] Consult Clark's *Practical Methods in Microscopy*, pp. 67–70.

[3] The epidermis may be started with a sharp knife, then peeled off with small forceps, and mounted in water for microscopical examination.

Examine another slice from the upper surface.

How does the number of *stomata* in the two cases compare?

Take measurements from the last three sketches with a scale and, knowing what magnifying power was used, answer these questions:[1]

(*a*) How thick is the epidermis?

(*b*) What is the length and the breadth of the epidermal cells?

(*c*) What is the average size of the pulp-cells?

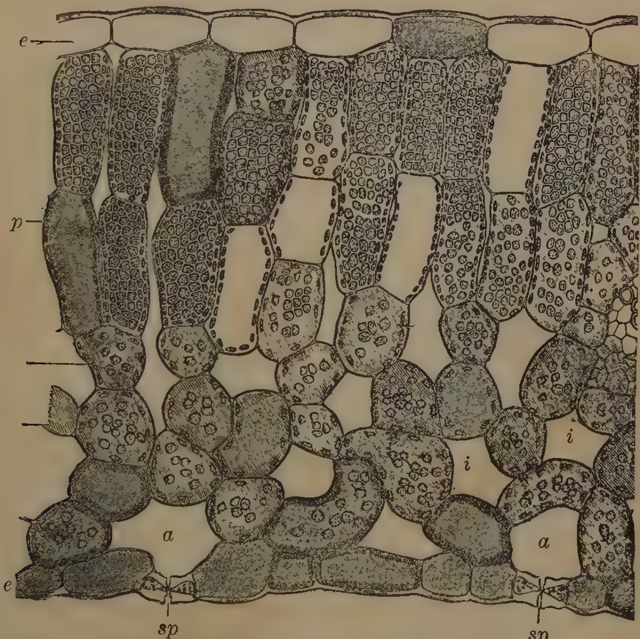


FIG. 96. — Vertical Section of the Leaf of the Beet. (Much magnified.)

e, epidermis; *p*, palisade cells (and similar elongated cells); *i*, intercellular spaces; *a*, air-spaces communicating with the stomata; *sp*, stomata, or breathing-pores.

136. *Uses of the Parts Examined.* — It will be most convenient to discuss the uses of the parts of the leaf a little

[1] The teacher may measure the size with the *camera lucida*.

later, but it will make matters simpler to state at once that the epidermis serves as a mechanical protection to the parts beneath and prevents excessive evaporation, that the palisade cells (which it may not be easy to make out very clearly in a roughly prepared section) help to prevent too rapid evaporation of sap from the leaf when exposed to excessive dryness, heat, and direct sunlight, and that they hold large quantities of the green coloring-matter of the leaf in a position where it

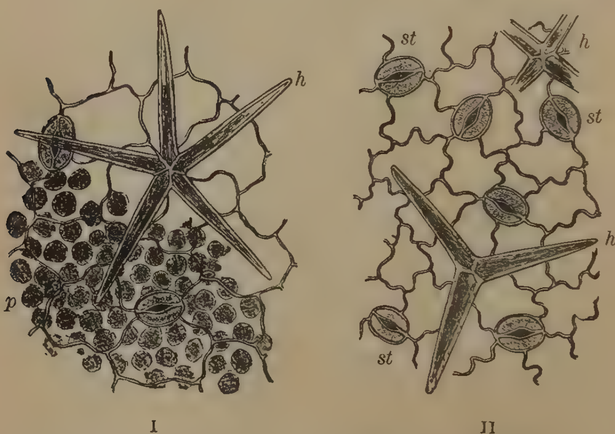


FIG. 97. — Epidermis of Leaf of Althæa. (Much magnified.)
I, from upper surface; II, from lower surface; *h*, star-shaped compound hairs; *st*, stomata; *p*, upper ends of palisade cells, seen through the epidermis.

can receive enough, but not too much sunlight. The stomata admit air to the interior of the leaf (where the air-spaces serve to store and to distribute it) and, above all, they regulate the evaporation of water from the plant.

137. *Leaf of "India-Rubber Plant."* [1] — Study with the microscope, as the lily leaf was studied, make the same set of sketches, note the differences in structure between the two leaves, and try to make out their meaning.

[1] *Ficus elastica.*

How does the epidermis of the two leaves compare?
Which has the larger stomata?
Which would better withstand great heat and long drought?

138. *Chlorophyll as found in the Leaf.* — Slice off a little of the epidermis from some such soft, pulpy leaf as that of the common field sorrel,[1] live-forever, or spinach; scrape from the exposed portion a very little of the green pulp; examine with the highest power attainable with your microscope, and sketch several cells.

Notice that the green coloring matter is not uniformly distributed, but that it is collected into little particles called *chlorophyll bodies* (Figs. 96, 98) and 205, *e*.

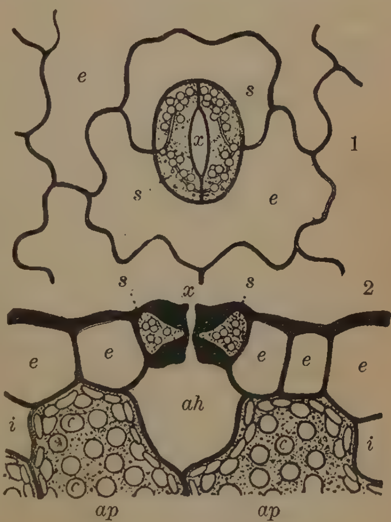


FIG. 98. — A Stoma of Thyme.

1, Surface view; *2*, Section; *e*, epidermal cells; *s*, guard-cells; *x*, stoma; *ah*, air-chamber; *ap*, pulp-cells of the leaf with chlorophyll bodies, *c*; *i*, intercellular air-spaces. (Both greatly magnified.)

139. *Woody Tissue in Leaves.* — The veins of leaves consist of fibro-vascular bundles containing wood and vessels much like those of the stem of the plant. Indeed, these bundles in the leaf are continuous with those of the stem, and consist merely of portions of the latter, looking as if unraveled, which pass outward and upward from the stem into the leaf under the name of *leaf-traces*. These traverse the petiole often in a somewhat irregular fashion. It is now easy to see that the dots noted on the leaf-scars of the horse-

[1] *Rumex acetosella.*

chestnut, Fig. 75, the black walnut, Fig. 58, and other trees, are merely the spots at which the leaf-traces passed from stem to petiole.

Experimental Study of Functions of Leaves. — The most interesting and profitable way in which to find out what work leaves do for the plant is by experimenting upon them. Much that relates to the uses of leaves is not readily shown in ordinary class-room experiments, but some things can readily be demonstrated in the experiments which follow.

140. ***Experiment 25.*** *Transpiration.* — Take two twigs or leafy shoots of any thin-leafed plant;[1] cover the cut end of each stem with a bit of grafting wax[2] to prevent evaporation from the cut surface. Put one shoot into a fruit jar, and leave in a warm room; screw the top on, put the other beside it, and allow both to remain some hours. Examine the relative appearance of the two, as regards wilting, at the end of the time.

Which shoot has lost most? Why? Has the one in the fruit jar lost any water? To answer this question, put the jar (without opening it) into a refrigerator; or, if the weather is cold, out of doors for a few minutes, and examine the appearance of the inside of the jar. What does this show?[3]

141. *Uses of the Epidermis.*[4] — The epidermis, by its toughness, tends to prevent mechanical injuries to the leaf, while by the transformation of a portion of its outer portion into a corky substance it greatly diminishes the loss of water from the general surface. In most cases, as in the india-rubber tree, the epidermal cells (and often two or three layers of cells beneath these) are filled with water, and thus serve as reservoirs from which the outer parts of the leaf and the stem are at times supplied.

In many cases, noticeably in the cabbage, the epidermis is

[1] Hydrangea, squash, melon or cucumber is best; many other kinds will answer very well.

[2] Grafting wax may be bought of nursery men or seedsmen.

[3] If the student is in doubt whether the jar filled with ordinary air might not behave in the same way, the question may be readily answered by putting a sealed jar of air into the refrigerator.

[4] See Kerner and Oliver's *Natural History of Plants*, vol. I, pp. 273–362.

covered with a waxy coating, which doubtless increases the power of the leaf to retain needed moisture, and which certainly prevents rain or dew from covering the leaf-surfaces, especially the lower surfaces, so as to prevent the operation of the stomata. Many common plants, like the meadow rue and the nasturtium, possess this power to shed water to such a degree that the under surface of the leaf is hardly wet at all when immersed in water, and the air-bubbles on the leaves give them a silvery appearance when held under water.

142. *Hairs on Leaves.* — Many kinds of leaves are more or less hairy or downy, as those of the mullein, the "mullein pink," many cinquefoils, and other common plants. In some instances this hairiness may be a protection against snails or other small leaf-eating animals, but in other cases it seems to be pretty clear that the woolliness (so often confined to the under surface) is to lessen the loss of water through the stomata. The Labrador tea is an excellent example of a plant, with a densely woolly coating on the lower surface of the leaf. The leaves, too, are partly rolled up, with the upper surface outward, so as to give the lower surface a sort of deeply-grooved form, and on this lower surface all of the stomata are placed. This plant, like some others with the same characteristics, ranges far north into regions where the temperature, even during summer, often falls so low that absorption of water by the roots ceases, since it has been shown that this stops a little above the freezing point of water. Exposed to cold, dry winds, the plant would then often be killed by complete drying up if it were not for the protection afforded by the woolly, channeled under surfaces of the leaves.[1]

143. *Operation of the Stomata.* — The stomata serve to admit air to the interior of the leaf, and to allow moisture, in the form of vapor, to pass out of it. They do this not in a

[1] This adaptation is sufficiently interesting for class study.

passive way, as so many mere holes in the epidermis might, but to some extent they regulate the rapidity of transpiration, opening more widely in damp weather and closing in dry weather. The opening is produced by each of the guard-cells bending into a more kidney-like form than usual, and the closing by a straightening out of the guard-cells. The under side of the leaf, free from palisade cells and abounding in intercellular spaces, is especially adapted for the working of the stomata, and accordingly we find them in much greater numbers on the lower than the upper surface. On the other hand, the little flowerless plants known as liverworts, which lie prostrate on the ground, have their stomata on the upper surface, and so do the leaves of pond lilies, which lie flat on the water. In those leaves which stand with their edges nearly vertical, the stomata are distributed somewhat equally on both surfaces. Stomata occur on the epidermis of young stems, being replaced later by the lenticels. Those plants which, like the cacti, have no ordinary leaves, transpire through the stomata scattered over their general surfaces.

The health of the plant depends largely on the working and proper condition of the stomata, and one reason why plants in cities often fail to thrive is that the stomata become choked with dust and soot. In some plants, as the oleander, provision is made for the exclusion of dust by a fringe of hairs about the opening of each stoma. If the stomata were to become filled with water, their activity would cease until they were freed from it; hence many plants have their leaves, especially the under surfaces, protected by a coating of wax which sheds water.

144. ***Experiment 26.**** *Amount of Water lost by Transpiration.* — Procure a thrifty hydrangea[1] and a small "india-rubber plant,"[2] each growing in a small flower-pot, and with the number of square inches

[1] The common species of the greenhouses, *Hydrangea Hortensia.*
[2] This is really a fig, *Ficus elastica.*

of leaf-surface in the two plants not too widely different. Calculate the area of the leaf-surface for each plant, by dividing the surface of a piece of tracing cloth into a series of squares one-half inch on a side, holding an average leaf of each plant against this and counting the number of squares and parts of squares covered by the leaf. This area, multiplied by the number of leaves for each plant, will give approximately the total evaporating surface for each.

Transfer each plant to a glass battery jar of suitable size. Cover the jar with a piece of sheet lead, slit to admit the stem of the plant, invert the jar and seal the lead to the glass with a hot mixture of beeswax and rosin. Seal up the slit and the opening about the stem with grafting wax. A thistle-tube, such as is used by chemists, is also to be inserted, as shown in Fig. 99.[1] The mouth of this should be kept corked when the tube is not in use for watering.

FIG. 99. — A Hydrangea for Exp. 26.

Water each plant moderately and weigh them separately on a balance that is sensitive to one or two grams. Record the weights, allow the plants to stand in a sunny, warm room for 24 hours and reweigh.

Add to each plant just the amount of water which is lost,[2] and continue the experiment in the same manner for several days so as to ascertain, if possible, the effect upon transpiration of varying amounts of water in the atmosphere.

Calculate the average loss per 100 square inches of leaf-surface for each plant throughout the whole course of the experiment. Divide the greater loss by the lesser to find their ratio. Find the ratio of each plant's greatest loss per day to its least loss per day, and by comparing these ratios decide which transpires more regularly.

[1] It will be much more convenient to tie the hydrangea if one has been chosen that has but a single main stem. Instead of the hydrangea the common cineraria, *Senecio cruentus*, does very well.

[2] The addition of known amounts of water may be made most conveniently by measuring it in a cylindrical graduate.

Try the effect of supplying very little water to each, so that the hydrangea will begin to droop, and see whether this changes the relative amount of transpiration for the two plants. Vary the conditions of the experiment for a day or two as regards temperature, and again for a day or two as regards light, and note the effect upon the amount of transpiration.[1]

The structure of the fig leaf has already been studied. That of the hydrangea is looser in texture and more like the leaf of the lily or the beet, Fig. 96.

What light does the structure throw on the results of the preceding experiment?

145. *Experiment 27.* *Rise of Sap in Leaves.* — Put the freshly cut ends of the petioles of several thin leaves of different kinds into small glasses, each containing red ink to the depth of one-quarter inch or more. Allow them to stand for half an hour, and examine them by holding up to the light and looking through them to see into what parts the red ink has risen. Allow some of the leaves to remain as much as twelve hours, and examine them again. The red-stained portions of the leaf mark the lines along which, under natural conditions, sap rises into it. Cut across (near the petiole or midrib ends) all the principal veins of some kind of large thin leaf. Then cut off the petiole and at once stand the cut end, to which the blade is attached, in red ink. Repeat with another leaf and stand in water. What do the results teach?

In order to prevent wilting, the rise of sap during the life of the leaf must have kept pace with the evaporation from its surface. A little calculation will show that the amount of water thus daily carried off through the foliage of a large tree or the grass-blades on a meadow is enormous. A grass-plant has been found to give off its own weight of water every twenty-four hours, in hot, dry summer weather. This would make about $6\frac{1}{2}$ tons per acre every twenty-four hours for ordinary grass-fields, or rather over 2200 pounds of water from a field 50×150 feet (*i.e.*, a city lot).

These large amounts of water are absorbed, carried through the tissues of the plant, and then given off by the leaves simply because the plant-food contained in the soil-water is

[1] When the experiments on the hydrangea have been finished, it should be kept moderately watered and left sealed up until it is needed for a later experiment, § 157.

in a condition so diluted that great quantities of water must be taken in order to secure enough of the mineral and other substances which the plant demands from the soil.

Meadow hay contains about two per cent of potash, or 2000 parts in 100,000, while the soil-water of a good soil does not contain more than one-half part in 100,000 parts. It would therefore take 4000 tons of such water to furnish the potash for one ton of hay. But the moist surface of the root-hairs has considerable power to dissolve mineral matter from the soil. The grass-plants therefore absorb water containing much more potash than is above stated. Probably somewhat over 500 tons of water have been transpired by each ton of hay.

146. *Accumulation of Mineral Matter in the Leaf.* — Just as a deposit of salt is found in the bottom of a seaside pool of salt water which has been dried up by the sun, so old leaves are found to be loaded with mineral matter, left behind as the sap drawn up from the roots is evaporated through the stomata. A bonfire of leaves makes a surprisingly large heap of ashes. An abundant constituent of the ashes of burnt leaves is *silica*, a substance chemically the same as sand. This the plant is forced to absorb along with the potash, compounds of phosphorus, and other useful substances contained in the soil-water; but since the silica is of hardly any value to most plants, it often accumulates in the leaf as so much refuse. Lime is much more useful to the plant than silica, but a far larger quantity of it is absorbed than is needed; hence it, too, accumulates in the leaf.

147. *Details of the Work of the Leaf.*[1] — A leaf has four important functions to perform:

(1) Fixation of carbon.	(3) Excretion of water.
(2) Assimilation.[2]	(4) Respiration.

[1] See Kerner and Oliver's *Natural History of Plants*, vol. I, pp. 371–483.

[2] In many works on Botany, (1) and (2) are both compounded under the term assimilation.

148. *Absorption of Carbonic Acid Gas.* — Carbonic acid gas is a constant ingredient of the atmosphere, usually occurring in the proportion of about 4 parts in every 10,000 of air or $\frac{1}{25}$ of one per cent. It is a colorless gas, a compound of two simple substances or elements, carbon and oxygen, the former familiar to us in the forms of charcoal and graphite, the latter occurring as the active constituent of air.

Carbonic acid gas is produced in immense quantities by the decay of vegetable and animal matter, by the respiration of animals, and by all fires in which wood, coal, gas, or petroleum is burned.

Green leaves and the green parts of plants have the power of removing carbonic acid gas from the air (or in the case of some aquatic plants from water in which it is dissolved) and setting free part or all of the oxygen. This process is an important part of the work done by the plant in making over raw materials into food from which it forms its own substance.

149. *Experiment 28.* *Oxygen-Making in Sunlight.* — Place a green aquatic plant in a glass jar full of fresh water, in front of a sunny window.[1] Note the rise of oxygen bubbles. Remove to a dark closet for a few minutes and examine by lamplight, to see whether the rise of bubbles still continues.

This gas may be shown to be oxygen by collecting some of it in a small inverted test-tube filled with water, and thrusting the glowing coal of a match just blown out into the gas. It is not, however, very easy to do this satisfactorily before the class.

Repeat the experiment, using water which has been well boiled and then quickly cooled. Boiling removes all the dissolved gases from water, and they are not re-dissolved in any considerable quantity for many hours.

Ordinary air, containing a known per cent of carbonic acid gas, if

[1] *Elodea*, *Myriophyllum*, *Chrysosplenium*, *Fontinalis*, any of the aquatic green flowering plants, or even the common confervaceous plants known as *pondscum* or "frog-spit," will do for this experiment.

passed very slowly over the foliage of a plant covered with a bell glass and placed in full sunlight, will, if tested chemically, on coming out of the bell glass be found to have lost a little of its carbonic acid. The pot in which the plant grows must be covered with a lid, closely sealed on, to prevent air charged with carbonic acid gas (as the air of the soil is apt to be) from rising into the bell glass.

150. *Disposition made of the Absorbed Carbonic Acid Gas.* — It would lead the student too far into the chemistry of botany to ask him to follow out in detail the changes by which carbonic acid gas lets go part at least of its oxygen, and gives its remaining portions, namely the carbon, and perhaps part of its oxygen, to build up the substance of the plant. Starch is composed of three elements: Hydrogen (a colorless, inflammable gas, the lightest of known substances), carbon, and oxygen. Water is composed largely of hydrogen, and, therefore, carbonic acid gas and water contain all the elements necessary for making starch. The chemist cannot put these elements together to form starch, but the plant can do it, and starch-making goes on constantly in the green parts of plants when exposed to sunlight and supplied with water and carbonic acid gas. The seat of the manufacture is in the chlorophyll bodies, and protoplasm is without doubt the manufacturer, but the process is difficult to understand. No carbonic acid can be taken up and used by plants growing in the dark.

A very good comparison of the leaf to a mill has been made as follows:[1]

The mill:	Parenchyma cells of the leaf.
Raw material used:	Carbonic acid gas, water.
Milling apparatus:	Chlorophyll grains.
Energy by which the mill is run:	Sunlight.
Manufactured product:	Starch.
Waste product:	Oxygen.

[1] By Professor Geo. L. Goodale.

151. *Plants Destitute of Chlorophyll not Starch-Makers.* — Aside from the fact that newly formed starch-grains are first found in the chlorophyll bodies of the leaf and the green

FIG. 100. — A Group of Indian Pipe Plants (*Monotropa uniflora*). Saprophytes and colorless.

layer of the bark, one of the best evidences of the intimate relation of chlorophyll to starch-making is derived from the fact that plants which contain no chlorophyll cannot make

starch from water and carbonic acid gas. Parasites, like the dodder, which are destitute of green coloring-matter, cannot do this, neither can *saprophytes* or plants which live on decaying or fermenting organic matter, animal or vegetable. Most saprophytes, like the moulds, toadstools, and yeast, are flowerless plants of low organization, but there are a few (such as the Indian pipe, Fig. 100, which flourishes on rotten wood or among decaying leaves) that bear flowers and seeds.

152. *Detection of Starch in Leaves.* — Starch may be found in abundance by microscopical examination of the green parts of growing leaves, or its presence may be shown by testing the whole leaf with iodine solution.

153. ***Experiment 29.*** *Occurrence of Starch in Nasturtium Leaves.* — Boil some bean leaves or leaves of nasturtium (*Tropæolum*) in water for a few minutes to kill the protoplasmic contents of the cells and to soften and swell the starch-grains.

FIG. 101. — Leaf of Tropæolum partly covered with Disks of Cork and exposed to Sunlight.

Soak the leaves (after boiling) in strong alcohol for a day or two to dissolve out the chlorophyll, which would otherwise make it difficult to see the blue color of the starch test, if any were obtained. Rinse out the alcohol with plenty of water and then place the leaves for half an hour in a solution of iodine, rinse off with water and note what portions of the leaf, if any, show the presence of starch.

154. ***Experiment 30.*** *Consumption of Starch in Nasturtium Leaves.* — Select some healthy leaves of Tropæolum on a plant growing vigorously indoors or, still better, in the open air. Shut off the sunlight from parts of the selected leaves (which are to be left on the plant and as little injured as may be) by pinning circular disks of cork on opposite sides of the leaf, as shown in Fig. 101. On the afternoon of the next day remove these leaves from the plant and treat as described in the preceding experiment, taking especial pains to get rid of all the chlorophyll by changing the alcohol as many times as may be necessary. What does this experiment show in regard to the consumption of starch in the leaf? What has caused its disappearance?

155. *Assimilation.* — The fixation of carbonic acid, by combining a part of its constituents with a part of the constituents of water, to form starch, is only one special, though very important, case of *assimilation,* that is, of the manufacture by the plant, from foreign materials, of the chemical compounds which make up its substance. A rather better term than assimilation is *constructive metabolism.* Besides carbonic acid gas and water, ordinary green plants require as food some compound of nitrogen, such as nitrates and ammonium compounds, sulphur and phosphorus, in suitable combinations, compounds of iron, calcium, potassium, and, perhaps, of sodium and of chlorine.[1]

These substances are found occurring in minute quantities in the soil-water and in ordinary flowering plants are brought to the parenchyma cells of the leaves or of the green layer of the bark to be worked over into the constituents of the plant. All parts of the process are due to the activity of the *protoplasm* contained in the cells of the working portions of the plant. Protoplasm is the jelly-like or semi-fluid proteid substance to which the life and working power of every active cell are due. The student has already become acquainted with protoplasm, since most of the tissues which he has examined, except the epidermis, the dead portions of the corky layer of the bark, the heartwood, and the dry pith, have been composed of cells which contained much protoplasm and some of which, as the cambium layer, contained little else but protoplasm.

156. *Non-Constructive Metabolism.*[2] — Side by side with the transformation of the inorganic substances drawn from earth and air into starch, protoplasm and other characteristic vegetable substances, there occur a series of other changes

[1] There is evidently room for the teacher, if he wishes, to do much in the way of exhibiting to the class the chemical compounds from which, as raw materials, plants manufacture their tissues.

[2] See Kerner and Oliver's *Natural History of Plants*, vol. I, pp. 455–465.

known by the general name of metabolism. The change of starch into grape sugar or maltose is a characteristic instance of the non-constructive kind of metabolism. It is essential to the growth of the plant that many and complicated transformations of material should occur within it; for example, starch, oil, and such insoluble proteids as are deposited in the outer portion of the kernel of wheat and other grains are extremely well adapted to serve as stored nutriment, but, on account of their insoluble nature, are quite unfit to circulate through the tissues of the plant. The various kinds of sugar, on the other hand, are not well adapted for storage, since they ferment easily in the presence of warmth and moisture.

By metabolic processes the tissues of the plant and their contents are all constructed out of certain formative materials. From starch, sugars, or fats, cellulose, the material of ordinary cell walls, is made, and from various proteids protoplasm and the chlorophyll bodies are produced.

Two important differences between fixation of carbon and the non-constructive or destructive type of metabolism should be carefully noticed. Destructive metabolism goes on in the dark as well as in the light, and it does not add to the total weight of the plant.

157. *Excretion of Water and Respiration.*—Enough has been said in § 145 concerning the former of these processes. *Respiration* or breathing in oxygen and giving off carbonic acid gas is an operation which goes on constantly in plants, as it does in animals, and is necessary to their life. For, like animals, plants get the energy with which they do the work of assimilation, growth, reproduction, and performing their movements, from the oxidation or burning up of such combustible substances as they can use for that purpose; for instance, starch and sugar.[1]

[1] The necessity of an air supply about the roots of the plant may be shown by filling the pot or jar in which the hydrangea was grown, for the transpiration experiment, perfectly full of water and noting the subsequent appearance of the plant at periods 12 to 24 hours apart.

The amount of oxygen absorbed and of carbonic acid given off, is, however, so trifling compared with the amount of each gas passing in the opposite direction, while fixation of carbon is going on in sunlight, that under such circumstances it is difficult to observe the occurrence of respiration at all. In ordinary leafy plants the leaves (through their stomata) are the principal organs for absorption of air, but a good deal of air passes into the plant through the lenticels of the bark.

158. *The Fall of the Leaf.* — In the tropics trees retain most of their leaves the year round; a leaf occasionally falls, but no considerable portion of them drops at any one season.[1] The same statement holds true in regard to our cone-bearing evergreen trees, such as pines, spruces, and the like. But the impossibility of absorbing soil-water when the ground is at or near the freezing temperature (§ 142) would cause the death, by drying up, of trees with broad leaf-surfaces in a northern winter. And in countries where there is much snow-fall, most broad-leafed trees could not escape injury to their branches from overloading with snow, except by encountering winter storms in as close-reefed a condition as possible. For such reasons our common shrubs and forest trees (except the cone-bearing, narrow-leafed ones already mentioned) are mostly *deciduous*, that is, they shed their leaves at the approach of winter.

159. *Chemical Changes in the Leaf before its Fall.* — The fall of the leaf is preceded by important changes in the contents of its cells.

Experiment 31. — *Does the Leaf vary in its Starch Contents at Different Seasons?*

Collect in early summer some leaves of several kinds of trees and shrubs, and preserve them in alcohol. Collect others as they are beginning to drop from the trees in autumn, and preserve them in the same way. Test some of each lot for starch as described in § 153.

What does the result indicate?

[1] Except where there is a severe dry season.

Much of the sugary and protoplasmic contents of the leaf disappears before it falls. These valuable materials have been absorbed by the branches and roots, to be used again the following spring.

The separation of the leaf from the twig is accomplished by the formation of a layer of cork cells across the base of the petiole in such a way that the latter finally breaks off across the surface of the layer. A waterproof scar is thus already formed before the removal of the leaf, and there is no waste of sap dripping from the wound where the leaf-stalk has been removed, and no chance for moulds to attack the bark or wood and cause it to decay. In compound leaves each leaflet may become separated from the petiole as the latter does from its attachment to the twig, as is notably the case with the horse-chestnut leaf (Fig. 75), or in a few kinds of simple leaves the blade may separate from its petiole, as it does in the Boston ivy (*Ampelopsis Veitchii*).

The brilliant coloration, yellow, scarlet, deep red and purple, of autumn leaves is popularly but wrongly supposed to be due to the action of frost. It depends merely on the changes in the chlorophyll grains and the liquid cell contents that accompany the withdrawal of the proteid material from the tissues of the leaf. The chlorophyll turns into a yellow insoluble substance after the valuable materials which accompany it have been taken away, and the cell-sap at the same time may turn red. Frost perhaps hastens the break-up of the chlorophyll, but individual trees often show bright colors long before the first frost, and in very warm autumns most of the changes in the foliage may come about before there has been any frost.

CHAPTER XIII.

Protoplasm and its Properties.[1]

160. *The Cell in its Simplest Form.* — Sufficient has been said in the preceding chapters, and enough tissues have been microscopically studied, to make it pretty clear what vegetable cells, as they occur in flowering plants, are like. But in studying the minute anatomy of bark, wood, pith, and other tissues, the attention is often directed to the *cell wall*, without much regard to the nature of the *cell contents*. Yet the cell wall is not the cell, any more than the lobster-shell or the crayfish-shell is the lobster or the crayfish. *The protoplasm is the cell.*[2] The cell, reduced to its lowest terms, need not have a cell wall, but may consist simply of a mass of protoplasm, usually containing a portion of denser consistency than the main bulk, known as the *nucleus*.

Such cells, without a cell wall, are not common in the vegetable world, but are frequently met with among animals.

161. *The Slime-Moulds.*[3] — The best example, among plants, of masses of naked protoplasm leading an individual existence is found in the slime moulds, which live upon rotten tan bark, decaying wood, and so on. These, like most flowerless plants, spring from minute bodies called *spores*, Fig. 102, *a*, which differ from the seeds of flowering plants, not only in

[1] If the teacher prefers to complete the study of the structure and functions of flowering plants before taking up lower forms, he may omit the present and the following chapter until after the flower and the fruit have been studied. It seems better to the author, however, to introduce the morphology and physiology of cells as individuals pretty early, and there are many reasons for taking up these topics immediately after Chapter IV.

[2] See Kerner and Oliver's *Natural History of Plants*, vol. I, pp. 21–51.

[3] Strasburger, Noll, Schenk, and Schimper, *Lehrbuch*, pp. 43, 44, 264, 265.

their microscopic size, but still more in their lack of an embryo. The spores of slime-moulds are capable, when kept dry, of preserving for many years their power of germination,

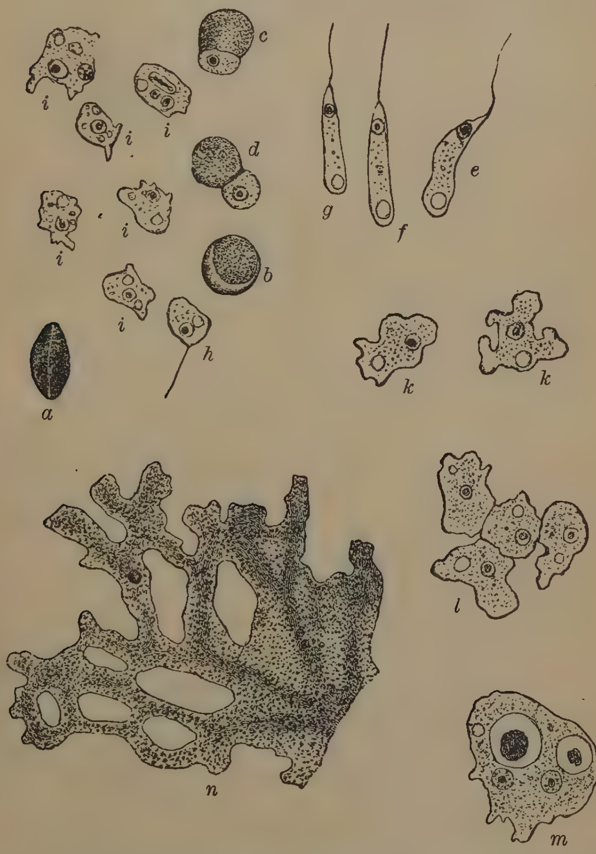


FIG. 102. — A Slime-Mould. (*a–m*, inclusive, magnified 540 times, *n* magnified 90 times.)

but in the presence of moisture and warmth they will germinate as soon as they are scattered. During the process of

germination the spore swells as shown at *b* and then bursts, discharging its protoplasmic contents, as seen at *c* and *d*. This in a few minutes lengthens out and produces at one end a hair-like *cilium*, as shown at *e*, *f*, *g*. These ciliated bodies are called *swarm-spores,* from their power of swimming freely about by the vibrating motion of the cilia. Every swarm-spore has at its ciliated end a *nucleus,* and at the other end a bubble-like object which gradually expands, quickly disappears, and then again expands. This *contractile vacuole* is commonly met with in animalcules, and increases the likeness between the slime-moulds and many microscopic animals. The next change of the swarm-spores is into an *Amœba-form* (so-called from one of the most interesting and simplest of animals, the *Amœba,* found on the surface of mud and the leaves of water-plants). In this condition, as shown at *h*, *i*, *k*, the spores creep about over the surface of the decaying vegetable material on which the slime-moulds live. Their movement is caused by a thrusting out of the semi-liquid protoplasm on one side of the mass, and a withdrawal of its substance from the other side. At length many amœba-shaped bodies unite, as at *l*, to form a larger mass, *m*, which finally increases to the protoplasmic network shown at *n*. This eventually collects into a roundish or egg-shaped, firm body, inside of which a new crop of spores is produced. It is not easy to trace the manner in which the nourishment of these simple plants is taken. Probably they absorb it from the decaying matter upon which they live during their amœba-like period, and after they have formed the larger masses, *n*.

162. *Characteristics of Living Protoplasm.*[1] — The behavior of the slime-moulds during their growth and transformations, as just outlined, affords a fair idea of several of the remarkable powers which belong to living protoplasm, which have been summed up as follows :

[1] See Huxley's *Essays*, vol. I, essay on " The Physical Basis of Life."

(1) The power to take up new material into its own substance (*selective absorption*). This is not merely a process of soaking up liquids, such as occurs when dry earth or a sponge is moistened. The protoplasmic lining of a root-hair, for example, selects from the soil-water some substances and rejects others.

(2) The ability to change certain substances into others of different chemical composition (*metabolism*, §§ 155, 156). Carbonic acid gas and water, losing some oxygen in the process, are combined into starch; starch is changed into various kinds of sugar and these back into starch again; or starch becomes converted into vegetable acids, into cellulose, or into oil. Many other more complicated transformations occur.

(3) The power to cast off waste or used up material (*excretion*). Getting rid of surplus water (§ 145) and of oxygen (§§ 148, 149, 150) constitutes a very large part of the excretory work of plants.

(4) The capacity for growth and the production of offspring (*reproduction*). These are especially characteristic of living protoplasm. It is true that non-living objects may grow in a certain sense, as an icicle or a crystal of salt or of alum in a solution of its own material does. But growth by the process of taking suitable particles into the interior of the growing substance and arranging them into an orderly structure is possible only in the case of live protoplasm.

(5) The possession of the power of originating movements not wholly and directly caused by any external impulse (*automatic movements*). Such, for instance, are the lashing movements of the cilia of the swarm-spores of slime-moulds or of the motile cells of the minute plants known as *Protococcus* (§ 268), or the slow vibrating movements of the stipules of the "telegraph plant" (*Desmodium*), not uncommon in greenhouses.

(6) The power of shrinking or closing up (*contractility*).

This is illustrated by the action of the contractile vacuole of the slime-moulds and of many animalcules as well as by the movements of leaves which act as insect-traps (§ 130) and by all the muscular movements of animals.

(7) Sensitiveness when touched or otherwise disturbed (*irritability*). This is shown by insect-catching leaves (§ 130), by the leaves of the common sensitive-plants, and by some parts of certain flowers (§ 209).

(1), (2), and (3) are not so readily studied in the slime-moulds as in some other plants, but unless one can believe in the manufacture of something out of nothing, he must conclude that these simple plants make their growth at the expense of materials drawn from the water and the decaying matter on which they are found.[1]

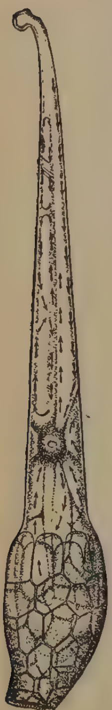


FIG. 103. — Stinging Hair of Nettle, with Nucleus. The arrows show the direction of the currents in the protoplasm.

163. *Circulation of Protoplasm.* — When confined by a cell wall, protoplasm often manifests a beautiful and constant rotating movement, traveling incessantly up one side of the cell and down the other.[2] A more complicated motion is the *circulation of protoplasm*, shown in cells of the jointed blue hairs in the flower of the common spiderwort and in the stinging hairs of the nettle (Fig. 103). The thin cell wall of each hair is lined with a protoplasmic layer in which are seen many irregular, thread-like currents, marked by the movements of the granules of which the protoplasmic layer is full.

[1] It would of course be well for the pupil to make careful studies of *Amœba* and of one or more of the ciliated animalcules. If time will admit of this, the teacher may consult Huxley and Martin's *Elementary Biology*, under *Amœba* and *Vorticella*.

[2] See Huxley and Martin, under *Chara*.

CHAPTER XIV.

Inflorescence, or Arrangement of Flowers on the Stem.

164. *Regular Positions for Flower-Buds.* — Flower-buds, like leaf-buds, occur regularly either in the axils of leaves or at the end of the stem or branch (see § 187) and are therefore either axillary or terminal.

165. *Axillary and Solitary Flowers; Indeterminate Inflorescence.* — The simplest possible arrangement for flowers which arise from the axils of leaves is to have a single flower spring from each leaf-axil. Fig. 104 shows how this plan appears in a plant with opposite leaves. As long as the stem continues to grow, the production of new leaves may be followed by that of new flowers. Since there is no definite limit to the number of flowers which may appear in this way, the mode of flowering just described (with many others of the same general character) is known as *indeterminate inflorescence.*

FIG. 104. — Axillary and Solitary Flowers of Pimpernel.

FIG. 105. — Raceme of Common Red Currant; *p.*, peduncle; *p′.*, pedicel; *br.*, bract.

The Raceme and Related Forms. — If the leaves along the stem were to become very much dwarfed and the flowers brought closer together, as they frequently are, a kind of flower-cluster like that of the currant (Fig. 105) or the lily of the valley would result. Such an inflorescence is called a *raceme;* the main flower stalk is known as the *peduncle;* the little individual flower stalks are *pedicels,* and the small, more or less scale-like leaves of the peduncle are *bracts.*[1]

Frequently the lower pedicels of a cluster on the general plan of the raceme are longer than the upper ones and make a somewhat flat-topped cluster, like that of the hawthorn, the sheep laurel, or the trumpet creeper. This is called a *corymb.*

FIG. 106.— Simple Umbel of Cherry.

In many cases, for example the parsnip, the sweet cicely, the ginseng and the cherry, a group of pedicels of nearly equal length spring from about the same point. This produces a flower-cluster called the *umbel* (Fig. 106).

166. *Sessile Flowers and Flower-Clusters.* — Often the pedicels are wanting, or the flowers are sessile, and then a modification of the raceme is produced which is called a *spike,* like that of the plantain (Fig. 107). The willow, alder, birch, poplar, and many other common trees bear a short, flexible, rather scaly spike (Fig. 108), which is called a *catkin.*

The peduncle of a spike is often so much shortened as to bring the flowers into a somewhat globular mass. This is

[1] It is hardly necessary to say that the teacher will find it better in every way, if material is abundant, to begin the study of flower-clusters with the examination of typical specimens by the class.

called a *head* (Fig. 109). Around the base of the head usually occurs a circle of bracts known as the *involucre*, well shown in Fig. 110. The same name is given to a set of bracts which often surround the bases of the pedicels in an umbel.

167. *The Anthodium.* — The plants of one large group, of which the dandelion, the daisy, the thistle, and the sunflower

FIG. 107.— Spike of Plantain.

I II

FIG. 108. — Catkins of Willow. I, Staminate flowers; II, Pistillate flowers.

FIG. 109. — Head of Eryngo.

are well-known members, bear their flowers in close involucrate heads on a common receptacle. The whole cluster looks so much like a single flower that it is usually taken for one by non-botanical people. This kind of head has received the special name of *anthodium*. In many of the largest and

most showy anthodia like the sunflower and the daisy there are two kinds of flowers, the *ray-flowers*, around the margin, and the tubular *disk-flowers* of the interior of the head, Fig. 110.[1] The early botanists supposed the whole flower cluster to be a single compound flower. This belief led to their naming one family of plants *Compositæ*, that is plants with compound flowers. In such anthodia as those of the thistle, the cud-weed and the everlasting there are no ray-flowers, and in others, like those

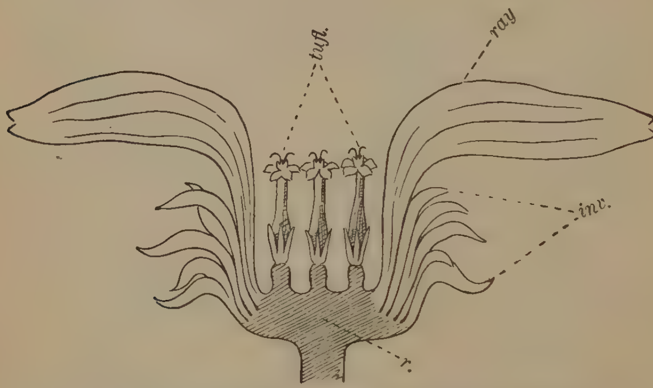


FIG. 110. — Vertical Section of Anthodium of a Sunflower (diagram). *inv.*, involucre; *ray*, ray-flower; *tu.-fl.*, tubular flowers of disk; *r.*, common receptacle.

of the dandelion and the chicory, all the flowers are ray-flowers.

168. *Compound Flower-Clusters.* — If the pedicels of a raceme branch, they may produce a compound raceme, or *panicle*, like that of the oat (Fig. 111).[1] Other forms of compound racemes have received other names.

An umbel may become compound by the branching of its

[1] Each disk-flower arises from the axil of a bract, not shown in the figure.
[2] Panicles may also be formed by compound cymes, see § 165.

flower-stalks (Fig. 112), each of which then bears a little umbel, an *umbellet.*

FIG. 111. — Panicle of Oat.

FIG. 112. — Compound Umbel of Chervil.

169. *Inflorescence Diagrams.* — The plan of inflorescence may readily be indicated by diagrams like those of Fig. 113.

FIG. 113. — Diagrams of Inflorescence.
A, panicle; *B*, raceme; *C*, spike; *D*, umbel[1]; *E*, head.[1]

[1] In these diagrams the balls, which symbolize flowers, should be largest at the outside and diminish regularly toward the centre, to show that the outermost flowers are the oldest.

The student should construct such diagrams for some rather complicated flower-clusters like those of the grape, horse-chestnut or buckeye, hardhack, vervain, or many grasses.

170. *Terminal Flowers. Determinate Inflorescence.* — The terminal bud of a stem may be a flower-bud. In this case the direct growth of the stem is stopped or determined by the appearance of the flower, hence such plants are said to have a *determinate inflorescence.* The simplest possible case of this kind is that in which the stem bears but one flower at its summit.

FIG. 114. — Compound Cyme of Mouse-Ear Chickweed.
t, the terminal (oldest) flower.

171. *The Cyme.*—Very often flowers appear from lateral (axillary) buds, below the terminal flower, and thus give rise to a flower-cluster called a *cyme.* This may have only three flowers, and in that case would look very much like a three-flowered umbel. But in the raceme, corymb, and umbel the order of flowering is from below upward, or from the outside of the cluster inward, because the lowest, or the outermost flowers, are the oldest, while in determinate forms of inflorescence the central flower is the oldest, and therefore the order of blossoming is from the centre outwards. Cymes are very commonly compound, like those of the elder and of many plants of the pink family, such as the Sweet William and the mouse-ear chickweed (Fig. 114). They may also, as already mentioned, be panicled, thus making a cluster much like Fig. 113 *A*.

CHAPTER XV.

The Study of Typical Flowers.[1]

(Only one of the three flowers described to be studied by aid of these directions.)

172. *The Flower of the Trillium.* — Cut off the flower stalk rather close to the flower; stand the latter, face down, on the table, and draw the parts then shown. Label the three green leaflike parts *sepals*, and the three white parts which alternate with these *petals*. Turn the flower face up, and make another sketch, labeling the parts as before, together with the yellow enlarged extremities or *anthers* of the six stamens.

Note the way in which the petals alternate with the sepals; *i.e.*, each petal springs from a point just above the space between two sepals. Observe the arrangement of the edges of the petals toward the base — one petal with both edges outside the other two, one with both edges inside, the third with one edge in and one out.

Note the veining of both sepals and petals, more distinct in the former.[2]

[1] The buttercup and the trillium are suggested because they are early spring flowers, of which some species may be found in most of the states east of the Mississippi. They are tolerably large flowers, simple in their plan, differ much in the number and shape of the floral organs, and are respectively somewhat typical of large groups. Other flowers should be studied in much detail when the class is completing Chapter XIX. The description of the flower of the trillium, as found in this chapter, is true in details only of the white variety of *T. erectum*, but the account given would serve as a guide for the study of any of our species. The buttercup flower here described is that of *Ranunculus bulbosus*, but the description will hold good in the main for any of the larger-flowered species. The tulip is perhaps the simplest polypetalous and regular flower which can be had of florists as early as May 1, and therefore in ample time to serve as an introduction (for city pupils) to the study of floral structures. If the expense of procuring tulips enough for class study should make it impossible to use them, the teacher could easily make out a set of directions for the study of some such flower as the (slightly irregular) *pelargoniums*.

Sedum acre can very easily be supplied in quantity, if arrangements are made with florists to have it ready.

[2] In flowers with delicate white petals the distribution of the fibro-vascular bundles in these can usually be readily shown by standing the freshly-cut end of the peduncle in red ink for a short time, until colored veins begin to appear in the petals. The experiment succeeds readily with apple, cherry, or plum blossoms; with white gilliflower the coloration is very prompt. Lily of the valley is perhaps as interesting a flower as any on which to try the experiment, since the well-defined stained stripes are separated by portions quite free from stain, and the pistils are also colored.

Pull off a sepal and make a sketch of it, natural size; then remove a petal, flatten it out, and sketch it, natural size.

Observe that the flower-stalk is enlarged slightly at the upper end into a rounded portion, the *receptacle*, from which all the parts of the flower spring.

Note how the six stamens arise from the receptacle, three of them from points just within and above the origins of the petals, the other three from points between the petals. Remove the remaining petals (cutting them off near the bottom with a knife), and sketch the stamens, together with another object, the *pistil*, which stands in the centre.

Cut off one stamen, and sketch it as seen through the magnifying glass. Notice that it consists of a greenish stalk, the *filament*, and a broader portion, the *anther*, Fig. 116, *B*. The latter is easily seen to contain a prolongation of the green filament, nearly surrounded by a yellow substance. In the bud it will be found that the anther consists of two long pouches or *anther-cells*, which are attached by their whole length to the filament, and face inward (towards the centre of the flower). When the flower is fairly open, the anther-cells have already split down their margins, and are discharging a yellow, somewhat sticky powder, the *pollen*.

Examine one of the anthers with the microscope, using the two-inch objective (No. 1), and sketch it.

Cut away all the stamens, and sketch the pistil. It consists of a stout lower portion, the *ovary*, which is six-ridged or angled, and which bears at its summit three slender *stigmas*.

In another flower, which has begun to wither (and in which the ovary is larger than in a newly-opened flower), cut the ovary across about the middle, and try to make out with the magnifying glass the number of chambers or *cells* which it contains. Examine the cross-section with the two-inch objective; sketch it, and note particularly the appearance and mode of attachment of the undeveloped seeds or *ovules* with which it is filled. Make a vertical section of another rather mature ovary, and examine this in the same way.

Using a fresh flower, construct a diagram to show the relation of the parts on an imaginary cross-section, as illustrated in Fig. 135.[1] Construct a diagram of a longitudinal section of the flower, on the general plan of those in Fig. 133, but showing the contents of the ovary.

[1] It is important to notice that such a diagram is not a picture of the section actually produced by cutting through the flower crosswise at any one level, but that it is rather a *projection* of the sections through the most typical part of each of the floral organs.

173. *The Flower of the Tulip.*[1] — Make a diagram of a side view of the well-opened flower, as it appears when standing in sunlight. Observe that there are three outer flower leaves and three inner ones.[2] Label the outer set *sepals* and the inner set *petals*. In most flowers the parts of the outer set are greenish, and those of the inner set of some other color. In cases like the present, where the coloration is the same throughout, the name *perianth*, meaning around the flower, is applied to the two sets taken together. Note the white waxy bloom on the outer surface of the three outer segments of the perianth. What is the use of this? Note the manner in which the three inner segments of the perianth arise from the top of the peduncle, just above and alternating with the points of attachment of the three outer segments. In a flower not too widely opened, note the relative position of the three inner segments of the perianth, one wholly outside the other two, one wholly inside, the third with one edge in and one edge out.

Remove one of the sepals by cutting it off close to its attachment to the peduncle, and examine the veining by holding it up in a strong light and looking through it. Make a sketch to show the general outline and the shape of the tip.

Examine a petal in the same way, and sketch it.

Cut off the remaining portions of the perianth, leaving about a quarter of an inch at the base of each segment. Sketch the upright, triangular, pillar-like object in the centre, label it *pistil*, sketch the six organs which spring from around its base, and label these *stamens*.

Note the fact that each stamen arises from a point just above and within the base of a segment of the perianth. Each stamen consists of a somewhat conical or awl-shaped portion below, the *filament*, surmounted by an ovate linear portion, the *anther*. Sketch one of the stamens about twice natural size. Is the attachment of the anther to the filament such as to admit of any nodding or twisting movement of the former? In a young flower, note the two tubular pouches or anther-cells of which the anther is composed, and the slits by which these open. Observe the dark-colored *pollen* which escapes from the anther-cells and adheres to paper or to the fingers. Examine a newly opened anther with the microscope, using the two-inch objective, and sketch it.

Cut away all the stamens and note the two portions of the pistil, a triangular prism, the *ovary*, and three roughened scroll-like objects at the

[1] *Tulipa Gesneriana*. As the flowers are rather expensive, and their parts are large and firm, it is not absolutely necessary to give a flower to each pupil, but some may be kept entire for sketching and others dissected by the class. All the flowers must be single.

[2] Best seen in a flower which is just opening.

top, the three lobes of the *stigma*. Make a sketch of these parts about twice the natural size, and label them. Touch a small camel's-hair pencil to one of the anthers, and then transfer the pollen thus removed to the stigma. This operation is merely an imitation of the work done by insects which visit the flowers out of doors. Note how readily the pollen clings to the rough stigmatic surface. Examine this adhering pollen with the two-inch objective, and sketch a few grains of it, together with the bit of the stigma to which it clings. Compare this drawing with Fig. 140. Make a cross-section of the ovary about midway of its length, and sketch the section as seen through the magnifying glass. Label the three chambers shown, *cells of the ovary*,[1] and the white egg-shaped objects within, *ovules.*[2]

Make a longitudinal section of another ovary, taking pains to secure a good view of the ovules, and sketch as seen through the magnifying glass.

Making use of the information already gained and the cross-section of the ovary as sketched, construct a diagram of a cross-section of the entire flower on the same general plan as those shown in Fig. 135.[3]

Split a flower lengthwise,[4] and construct a longitudinal section of the entire flower on the plan of those shown in Fig. 133, but showing the contents of the ovary.

174. *The Flower of the Buttercup.* — Make a diagram of the mature flower as seen in a side view, looking a little down into it. Label the five pale greenish yellow, hairy, outermost parts sepals, and the five[5] larger bright yellow parts above and within these petals, and the yellow-knobbed parts which occupy a good deal of the interior of the flower, *stamens.*

Note the difference in the position of the sepals of a newly opened flower and that of the sepals about a flower which has opened as widely as possible. Note the way in which the petals alternate with the sepals, *i.e.*, each petal springs from a point just above the space between two sepals. In an opening flower, observe the arrangement of the edges of the petals, two entirely outside the others, two entirely inside, one with one edge in and the other out.

Cut off a sepal and a petal, each close to its attachment to the flower;

[1] Notice that the word cell here means a comparatively large cavity, and is not used in the same sense in which we speak of a wood cell or a pith cell.

[2] The section will be more satisfactory if made from an older flower, grown out of doors, from which the perianth has fallen.

[3] Consult also the footnote on p. 138.

[4] One will do for an entire division of the class.

[5] Sometimes more.

place both, face down, on a sheet of paper, and sketch about twice the natural size. Describe the difference in appearance between the outer and the inner surface of the sepal and of the petal. Note the little scale at the base of the petal, inside.

Strip off all the parts from a flower which has lost its petals, until nothing is left but a slender conical object a little more than an eighth of an inch in length. This is the *receptacle* or summit of the peduncle.

In a fully opened flower, note the numerous yellow-tipped *stamens*, each consisting of a short stalk, the *filament*, and an enlarged yellow knob at the end, the *anther*. Note the division of the anther into two portions, which appear from the outside as parallel ridges, but which are really closed tubes, the *anther-cells*.

Observe in the interior of the flower the somewhat globular mass (in a young flower almost covered by the stamens). This is a group of *pistils*. Study one of these groups in a flower from which the stamens have mostly fallen off, and make an enlarged sketch of the head of pistils. Remove some of the pistils from a mature head, and sketch a single one as seen with the magnifying glass. Label the little knob or beak at the upper end of the pistil *stigma*, and the main body of the pistil *ovary*. Make a section of one of the pistils, parallel to the flattened surfaces, like that shown in Fig. 169, and note the partially matured seed or *ovule* within.

CHAPTER XVI.

Plan and Structure of the Flower and its Organs.

175. *Parts or Organs of the Flower.* — Most showy flowers consist, like those studied in the preceding chapter, of four circles or sets of organs, the sepals, petals, stamens, and pistils. The sepals, taken together, constitute the *calyx*, the petals, taken together, constitute the *corolla*, Fig. 115.[1] Sometimes it is convenient to have a word to comprise both calyx and corolla; for this the term *perianth* is used. A flower which contains all four of these sets is said to be *complete*. Since the work of the flower is to produce seed, and seed-forming is due to the coöperation of stamens and pistils, these are known

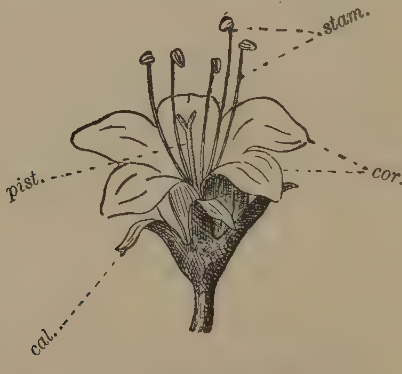


FIG. 115.—The Parts of the Flower.[2]
cal., calyx; *cor.*, corolla; *stam.*, stamens; *pist.*, pistil.

[1] The flower of the waterleaf or *Hydrophyllum*, modified by the omission of the hairs on the stamens, is here given because it shows so plainly the relation of the parts.

[2] *Hydrophyllum Canadense*, with appendages in throat of corolla and hairs on stamens omitted.

as the *essential organs*, Fig. 116. The simplest possible pistil is a dwarfed and greatly modified leaf (§ 188), adapted into a seed-bearing organ. Such a pistil may be one-seeded, as in Fig. 169, or several-seeded, as in the right-hand part of Fig. 171; it is called a *carpel*. The calyx and corolla are known

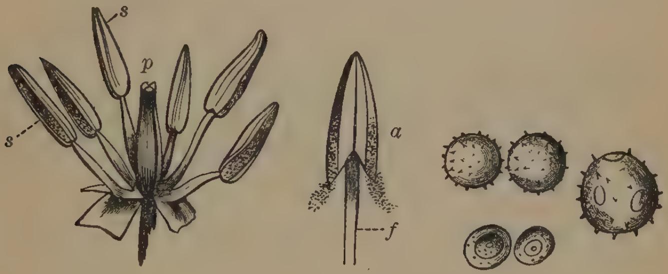


FIG. 116. — The Essential Organs.

A, stamens and pistil of a tulip (the perianth removed); *s*, stamens; *p*, pistil; *B*, a separate stamen, with its anther *a* discharging pollen; *f*, the filament; *C*, pollen-grains.

as the *floral envelopes*. Flowers which have the essential organs are called *perfect flowers*. They may therefore be perfect without being complete. In cases where the perianth contains only one row of parts, it is assumed that the petals are lacking. Such incomplete flowers are said to be *apetalous*, Fig. 117.

FIG. 117. — Apetalous Flower of (European) Wild Ginger.

176. *Regular and Symmetrical Flowers.* — A flower is regular if all the parts of the same set or circle are alike in size and shape, as in the stonecrop, Fig. 118. Such flowers as that of the violet, the monkshood, the nasturtium, or the laburnum, Fig. 119, are irregular. Symmetrical flowers are those whose calyx, corolla, circle of stamens and set of carpels consists each of the same number of parts, or in which the

number in every case is a multiple of the smallest number found in any set. The stonecrop is symmetrical, since it has five sepals, five petals, ten stamens, and five carpels. Roses, mallows, and mignonette are familiar examples of flowers

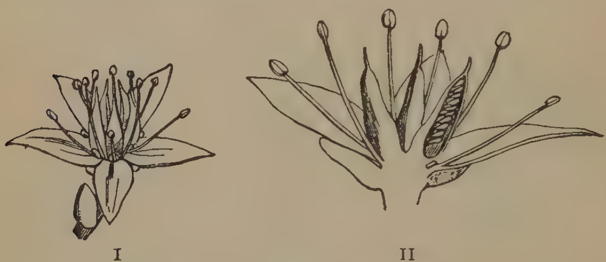


FIG. 118.—Flower of Stonecrop.
I, entire flower (magnified); II, vertical section (magnified).

which are unsymmetrical because they have a large indefinite number of stamens; the Portulaca is unsymmetrical since it has two divisions of the calyx, five or six petals, and seven to twenty stamens.

FIG. 119.—Irregular Corolla of Laburnum.
I, side view; II, front view.

177. *The Receptacle.* — The parts of the flower are borne on an expansion of the peduncle, called the *receptacle.* Usually, as in the flower of the grape, Fig. 145, this is only a slight enlargement of the peduncle, but in the lotus and the magnolia the receptacle is of great size, particularly after the

petals have fallen and the seed has ripened. The receptacle of the rose, Fig. 120, is hollow and the pistils arise from its interior surface.

178. *Imperfect or Separated Flowers.* — The stamens and pistils may be produced in separate flowers, which are, of course, *imperfect.* This term does not imply that such flowers do their work any less perfectly than others, but only that they have not both kinds of essential organs. In the very simple imperfect flowers of the willow, Fig. 121, each flower of the catkin, Fig. 108, consists merely of a pistil or a group of (usually two) stamens, springing from the axil of a small bract.

FIG. 120. — A Rose, Longitudinal Section.

Staminate and pistillate flowers may be borne on different plants, as they are in the willow, or they may be borne on the same plant, as in the hickory and the hazel, among trees, or in the castor-oil plant, Indian corn, and the begonias. When staminate and pistillate flowers are borne on separate plants, such a plant is said to be *diœcious,* that is, of-two-households; when both kinds of flower appear on the same individual, the plant is said to be *monœcious,* that is, of-one-household.

179. *Study of Imperfect Flowers.* — Examine, draw, and describe the imperfect flowers of some of the following diœcious plants and one of the monœcious plants[1]:

Diœcious plants	early meadow rue, willow, poplar.
Monœcious plants	walnut, oak, chestnut, hickory, alder, beech, birch, hazel, begonia.

[1] For figures and descriptions of these or allied flowers consult Gray's *Manual of Botany*, Emerson's *Trees and Shrubs of Massachusetts*, Newhall's *Trees of the Northern United States*, or Le Maout and Decaisne's *Traité Général de Botanique.*

180. *Union of Similar Parts of the Perianth.* — The sepals may join or *cohere* to form a calyx which is more or less entirely united into one piece, as in Figs. 115, 117. In this case the calyx is said to be *gamosepalous*, that is, of-wedded-sepals. In the same way the corolla is frequently *gamopetalous*, as in Figs. 122, 123. Special names are given to a large number of forms of the gamopetalous corolla, and these names are of great use in accurately describing plants; only a few of these names are here given, in connection with the figures.

When the parts of either circle of the perianth are wholly

I II
FIG. 121. — Flowers of Willow (magnified). I, staminate flower; II, pistillate flower.

FIG. 122. — Bell-Shaped Corolla of Bellflower (Campanula).

unconnected with each other, that is, polysepalous or polypetalous, they are said to be *distinct*.

181. *Parts of the Stamen and the Pistil.* — The stamen usually consists of a hollow portion, the *anther*, Fig. 127 *b*, borne on a stalk called the *filament*, Fig. 127 *a*. Inside the anther is a powdery or pasty substance called *pollen*. Not infrequently the filament is lacking. The pistil usually consists of a small hollow chamber, the *ovary*, which contains the ovules or rudimentary seeds, a slender portion or stalk, called the *style*, and at the top of this a ridge, knob, or point

called the *stigma*. These parts are all shown in Fig. 128. In many pistils the stigma is borne directly on the ovary, as in Fig. 145.

182. *Union of Stamens with each Other.* — Stamens may be wholly unconnected with each other or *distinct*, or they may cohere by their filaments into a single group, when they are said to be *monadelphous*, of-one-brotherhood, Fig. 129, into two groups (*diadelphous*), Fig. 130, or into many groups. In some flowers the stamens are held together in a ring by their coherent anthers, Fig. 131.

FIG. 123. — Salver-Shaped Corolla of Jasmine (magnified).

183. *Union of Pistils.* — The pistils may be entirely separate from each other, *distinct* and *simple* as they are in the buttercup and the stonecrop, or several may join to form one *compound pistil* of more or less united carpels. In the latter case the union generally affects the ovaries, but often leaves the styles separate, or it may result in joining ovaries and styles, but leave the stigmas separate or at any rate lobed, so as to show of how many separate carpels the compound pistil is made up. Even when there is no external sign to show the compound nature of the pistil, it can usually be recognized from the study of a cross-section of the ovary.

FIG. 124. — Wheel-Shaped Corolla of Potato.

184. *Cell of the Ovary; Placentas.* — Compound ovaries are very commonly several-celled, that is, they consist of a number of separate cells[1] or chambers. Fig. 132 *B* shows a

[1] Notice that the word cell is here used in an entirely different sense from that in which it has been employed in the earlier chapters of this book. As applied to the ovary, it means a chamber or compartment.

three-celled ovary, seen in cross-section. The ovules are not borne indiscriminately by any part of the lining of the ovary. In one-celled pistils they frequently grow in a line running along one side of the ovary, as in the pea pod, Fig. 176. The ovule-bearing line is called a *placenta;* in compound pistils there are commonly as many placentas as there are separate pistils joined to make the compound one. Placentas on the wall of the ovary, like those in Fig. 132 *A*, are called *parietal placentas;* those which occur as at *B*, in the same figure, are

FIG. 125. — Tubular Corolla, from Head of Bachelor's Button.

FIG. 126. — Labiate or Ringent Corolla of Dead Nettle.

FIG. 127. — Parts of a Stamen. *a*, filament; *b*, anther.

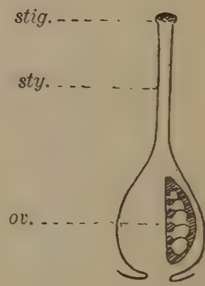


FIG. 128. — Parts of the Pistil. *ov.*, ovary; *sty.*, style; *stig.*, stigma.

said to be central, and those which, like the form represented in *C* of the same figure, consist of a column rising from the bottom of the ovary, are called *free central placentas.*

185. *Union of Separate Circles.* — The members of one of the circles of floral organs may join those of another circle, thus becoming *adnate*, *adherent*, or *consolidated.* In Fig. 117 the calyx-tube is adnate to the ovary. In this case the parts of the flower do not all appear to spring from the receptacle. Fig. 133 illustrates three common cases as regards insertion of the parts of the flower. In I they are

all inserted on the receptacle, and the corolla and stamens are said to be *hypogynous*, that is, beneath-the-pistil. In II the petals and the stamens appear as if they had grown fast to the calyx for some distance, so that they surround the pistil, and they are therefore said to be *perigynous*, that is, around-the-pistil. In III all the parts are *free* or uncon-

FIG. 129.—Monadelphous Stamens of Mallow.

FIG. 130. — Diadelphous Stamens of Sweet Pea.

FIG. 131. — Stamens of a Thistle, with Anthers United into a Ring.

a, united anthers; *f*, filaments, bearded on the sides.

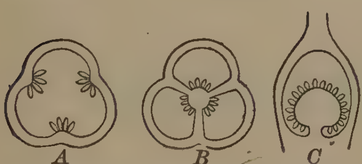


FIG. 132.—Principal Types of Placenta.

A, parietal placenta; *B*, central placenta; *C*, free central placenta; *A* and *B*, transverse sections; *C*, longitudinal section.

solidated, except the petals and stamens; the stamens may be described as *epipetalous*, that is, growing-on-the-petals. Sometimes some or all of the other parts seem to grow out of the ovary, and such parts are said to be *epigynous*, that is, on-the-ovary, like the petals and stamens of the white water-lily, Fig. 134.

186. *Floral Diagrams.* — Sections (real or imaginary)

through the flower lengthwise, like those of Fig. 133, help greatly in giving an accurate idea of the relative position of the floral organs. Still more important in this way are cross-sections, which may be recorded in diagrams like those of Fig. 135.[1] In constructing such diagrams it will often be necessary to suppose some of the parts of the flower to be raised or lowered from their true position, so as to bring

FIG. 133. — Insertion of the Floral Organs.

I, Hypogynous, all the other parts on the receptacle, beneath the pistil; II, Perigynous, petals and stamens apparently growing out of the calyx, around the pistil; III, corolla hypogynous, stamens epipetalous.

FIG. 134. — White Water-Lily. The inner petals and the stamens growing from the ovary.

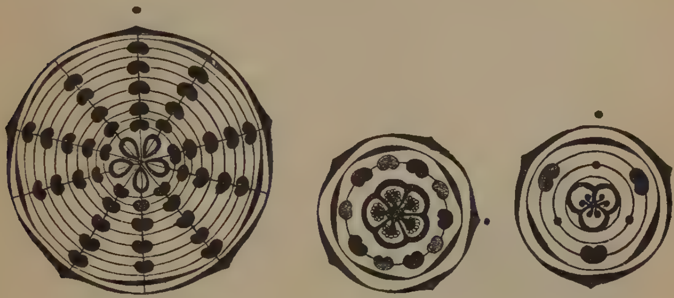
them into such relations that all could be cut by a single section. This would, for instance, be necessary in making a diagram for the cross-section of the flower of the white water-lily, of which a partial view of one side is shown in Fig. 134.[2]

Construct diagrams of the longitudinal section and the transverse section of several large flowers, following the

[1] For floral diagrams see *Thomé's Botany*, Le Maout and Decaisne's *Traite Général de Botanique*, or Eichler's *Blüthendiagramme*.

[2] It is best to begin practice on floral diagrams with flowers so firm and large that actual sections of them may be cut with ease and the relations of the parts in the section readily made out. The tulip is admirably adapted for this purpose.

method indicated in Figs. 133 and 135, but making the longitudinal section show the interior of the ovary.[1]



I II III

FIG. 135. — Diagrams of Cross-Sections of Flowers.

I, columbine; II, heath family; III, iris family. In each diagram the dot alongside the main portion indicates a cross-section of the stem of the plant. In II, every other stamen is more lightly shaded because some plants of the heath family have 5 and some 10 stamens.

[1] Among the many excellent early flowers for this purpose may be mentioned trillium, blood-root, dog-tooth violet, marsh marigold, buttercup, tulip tree, horse-chestnut, Jeffersonia, May-apple, cherry, apple, crocus, tulip, daffodil, primrose, wild ginger, cranesbill, locust, bluebell.

CHAPTER XVII.

True Nature of Floral Organs; Details of their Structure.

187. *The Flower a Shortened and Greatly Modified Branch.* —In Chapter IX, the leaf-bud was explained as being an undeveloped branch, which in its growth would develop into a real branch (or a prolongation of the main stem). Now since flower-buds appear regularly either in the axils of leaves or as terminal buds, there is reason to regard them as of similar nature to leaf-buds. This would imply that the receptacle corresponds to the axis of the bud shown in Fig. 60, and that the parts of the flower correspond to leaves. There is plenty of evidence that this is really true. Sepals frequently look very much like leaves, and in many cactuses the bracts about the flower are so sepal-like that it is impossible to tell where the bracts end and the sepals begin. The same thing is true of

FIG. 136. — Transitions from Petals to Stamens in White Water-Lily.
E, F, G, H, various steps between petal and stamen.

sepals and petals in such flowers as the white water-lily. In this flower there is a remarkable series of intermediate steps ranging all the way from petals, tipped with a bit of anther, through stamens with a broad petal-like filament to regular stamens, as is shown in Fig. 136, E, F, G, H. The same thing is shown in many double roses (Fig. 137). In completely double flowers all the essential organs are transformed by cultivation into petals. In the flowers of the cultivated double cherry the pistils occasionally take the form of small leaves, and some roses turn wholly into green leaves.

Summing up, then, we know that flowers are altered and shortened branches: (1) because flower-buds have the same

FIG. 137. — Transitions between Petals and Stamens in a Rose.

kinds of origin as leaf-buds; (2) because all the intermediate steps are found between bracts on the one hand and stamens on the other; (3) because the essential organs are found to be replaced by petals or even by green leaves.

188. *Mode of Formation of Stamens and Pistils from Leaves.* — It is hardly possible to state, in a book for beginners, how stamens stand related to leaves.[1]

The simple pistil or *carpel* is supposed to be made on the plan of a leaf folded along the midrib until its margins touch, like the cherry leaf in Fig. 61. But the student must not understand by this statement that the little pistil leaf grows

[1] "The anther answers exactly to the spore-cases of the ferns and their allies, while the filament is a small specialized leaf to support it." For a fuller statement, see Potter's Warming's *Systematic Botany*, pp. 236, 237.

at first like an ordinary leaf and finally becomes folded in. What really occurs is this: the flower-bud, as soon as it has developed far enough to show the first rudiments of the essential organs, contains them in the form of minute knobs. These are developed from the tissues of the plant in the same manner as are the knobs in a leaf-bud, which afterwards become leaves; but as growth and development progress in the flower-bud, its contents soon show themselves to be stamens and pistils (if the flower is a perfect one). The united leaf margins near the tip would form the stigma, and the placenta would correspond to the same margins, rolled slightly inwards, extending along the inside of the inflated leaf pouch. Place several such folded leaves upright about a common center, and their cross-section would be much like that of B in Fig. 132. Evidence that carpels are really formed in this way may be gained from the study of such fruits as that of the monkshood (Fig. 171), in which the ripe carpels may be seen to unfold into a shape much more leaf-like than that which they had while the pistil was maturing.

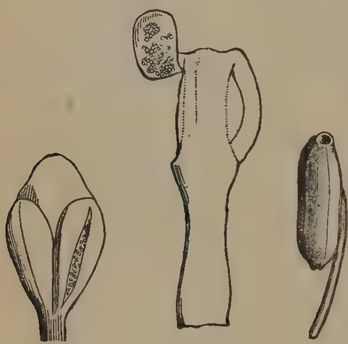


FIG. 138. — Modes of Discharging Pollen.

I, by longitudinal slits in the anther-cells (pine); II, by uplifted valves (barberry); III, by a pore at the top of each anther-lobe (rhododendron).

189. *The Anther and its Contents.* — Some of the shapes of the anthers may be learned from Figs. 116, 129, 136, 138 and 155.[1] The shape of the anther and the way in which it opens depend largely upon the way in which the pollen is to be dis-

[1] See Kerner and Oliver, vol. II, pp. 86–95.

charged and how it is carried from flower to flower. The commonest method is to have the anther-cells split lengthwise, as in Fig. 138, I. A few anthers open by trap-doors like valves, as in II, and a larger number by little holes at the top, as in III.

The pollen, in many plants with inconspicuous flowers, as the evergreen cone-bearing trees, the grasses, rushes, and sedges, is a fine, dry powder. In plants with showy flowers it is often somewhat sticky or pasty. The forms of pollen-grains are extremely various. That of the tulip (Fig. 116), and the kinds shown in Fig. 139 will serve as examples of some of the shapes which the grains assume; IV in the latter figure is perhaps as common a form as any. Each pollen-grain consists mainly of a single cell, and is covered by a moderately thick outer wall and a thin inner one. Its contents is a thickish protoplasm, full of little opaque particles and usually containing grains of starch and little drops of oil. The larger knobs on the outer coat, as at *k* (Fig. 139, I and II), mark the spots at which the inner coat of the grain is finally to burst through the outer one, pushing its way out in the form of a slender, thin-walled tube.[1]

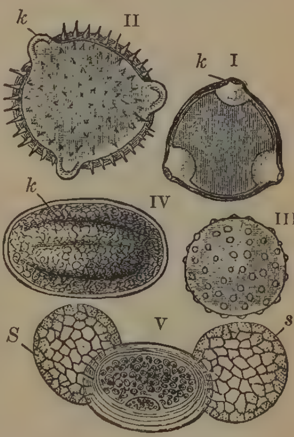


FIG. 139. — Pollen-Grains.
I, hazel; II, coltsfoot; III, wild ginger; IV, hepatica; V, pine; *s s*, air-sacs. (All magnified 300 diameters.)

190. ***Experiment 32.*** *Production of Pollen Tubes.* — Place a few drops of suitably diluted syrup[2] with some fresh pollen in a concave cell ground in a microscope slide; cover with thin glass circle; place under

[1] See Kerner and Oliver, vol. II, pp. 95–104. [2] See Appendix B.

a bell glass, with a wet cloth or sponge, to prevent evaporation of the syrup, and set aside in a warm place, or merely put some pollen in syrup in a watch crystal under the bell glass. Examine from time to time to note the appearance of the pollen tubes. Try several kinds of pollen if possible, using syrups of various strengths. The following kinds of pollen form tubes readily in syrups of the strengths indicated :

Tulip	1 to 3 per cent.
Narcissus	3 to 5 "
Cytisus Canariensis (called Genista by florists)	15 "
Chinese primrose	10 "
Sweet pea[1]	10 to 15 "
Tropæolum[1]	15 "

FIG. 140. — Stigma of Thorn Apple (Datura) with Pollen (magnified).

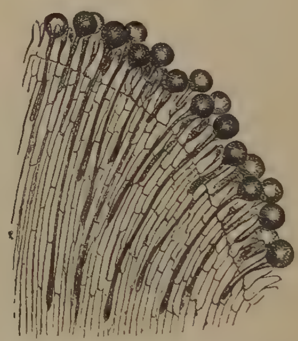


FIG. 141. — Part of Stigma of Thorn Apple. Vertical section (magnified), showing pollen tubes making their way toward the ovary.

191. *Microscopical Structure of the Stigma and Style.* — Under a moderate power of the microscope the stigma is seen to consist of cells arranged rather loosely over the surface, and secreting a moist liquid to which the pollen-grains adhere (Fig. 140). Beneath these superficial cells and running down

[1] The sweet pea pollen and that of Tropæolum are easier to manage than any other kinds of which the author has personal knowledge. If a concaved slide is not available, the cover-glass may be propped up on bits of the thinnest broken cover-glasses. From presence of air or some other reason, the formation of pollen tubes often proceeds most rapidly just inside the margin of the cover-glass.

through the style (if there is one), there are found long cells sometimes with intermediate spaces, through which latter the pollen tubes readily find their way (Fig. 141). When no such intercellular spaces exist, the pollen tube proceeds through the cell walls, which it softens by means of a substance which it exudes for that purpose.

192. *Structure of the Ovule.* — The details of the microscopic anatomy of the ovule are rather complicated. It is enough for our present purpose to state that the young ovule, before it has begun to form an embryo, usually exists as a roundish or egg-shaped mass, with a small opening leading into its apex. This opening leads to a sac inside the ovule, filled with soft protoplasmic material, containing cells and known as the *embryo sac.* Minute cells occur at the apex of the ovule (Fig. 142), and it is from their growth and development that the embryo is at length produced.

CHAPTER XVIII.

Fertilization; Transfer of Pollen, Protection of Pollen.

193. *Fertilization.* — By fertilization in flowering plants the botanist means the union of a nucleus from a pollen-grain with that of a cell at the apex of the *embryo sac* (Fig. 142). This process gives rise to a cell which contains material derived from the pollen and from the ovule cell. In a great many plants the pollen, in order to accomplish the most successful fertilization, must come from another plant of the same kind, not from the individual which bears the ovules that are being fertilized.

Pollen tubes begin to form soon after pollen-grains lodge on the stigma. The time required for the process to begin varies in different kinds of plants, requiring in many cases twenty-four hours or more. The length of time needed for the pollen tube to make its way through the style to the ovary depends upon the length of the style and other conditions. In the crocus, which has a style several inches long, the descent takes from one to three days.

Finally the tube penetrates the opening at the apex of the ovule *m*, in Fig. 142, reaches one of the cells shown at *e*, and transfers a nucleus into this egg-cell. The latter is thus enabled to divide and grow rapidly into an embryo. This the cell does by forming cell walls and then increasing by continued subdivision in much the same way in which the cells at the growing point near the tip of the root, or those of the cambium layer subdivide.[1]

194. *Nature of the Fertilizing Process.* — The necessary feature of the process of fertilization is *the union of the essential contents of two cells to form a new one, from which the*

[1] See Kerner and Oliver, vol. II, pp. 401–420.

future plant is to spring. This kind of union is found to occur in many flowerless plants (Chapter XXIII), resulting in the production of a spore very unlike a seed in most respects, but capable of growing into a complete plant like that which produced it.

195. *Number of Pollen Grains to each Ovule.* — Only one pollen tube is necessary to fertilize each ovule, but so many pollen-grains are lost that plants produce many more of them than of ovules. The ratio, however, varies greatly. In the night-blooming cereus there are about 250,000 pollen-grains for 30,000 ovules, or rather more than 8 to 1, while in the common garden wistaria there are about 7,000 pollen grains to every ovule, and in Indian corn, the cone-bearing evergreens, and a multitude of other plants, many times more than 7,000 to 1. These differences depend, as will be seen presently, upon the mode in which the pollen is carried from the stamens to the pistil.

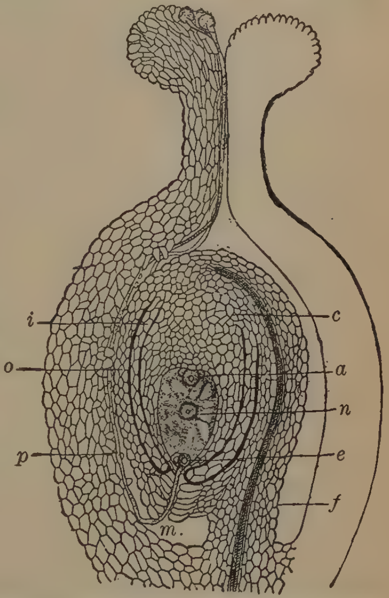


FIG. 142. — Diagrammatic Representation of Fertilization of an Ovule.

i, inner coating of ovule; *o*, outer coating of ovule; *p*, pollen tube, proceeding from one of the pollen-grains on the stigma; *c*, the place where the two coats of the ovule blend. (The kind of ovule here shown is inverted, its opening *m* being at the bottom, and the stalk *f* adhering along one side of the ovule.) *a* to *e*, embryo sac, full of protoplasm; *a*, so-called antipodal cells of embryo sac; *n*, central nucleus of the embryo sac; *e*, nucleated cells, one of which receives the essential contents of the pollen tube; *f*, funiculus or stalk of ovule; *m*, opening into the ovule.

196. *Cross-Fertilization and Self-Fertilization.*—It was long supposed by botanists that the pollen of any perfect flower needed only to be placed on the stigma of the same flower to insure satisfactory fertilization. But in 1857 and 1858 the great English naturalist, Charles Darwin, stated that certain kinds of flowers were entirely dependent for fertilization on the transference of pollen from one plant to another, and he and other botanists soon extended the list of such flowers until it came to include most of the showy, sweet-scented or otherwise conspicuous kinds. It was also shown that probably nearly all attractive flowers, even if they can produce some seed when self-fertilized, do far better when fertilized with pollen from the flowers of another plant.[1] This important fact was established by a long series of experiments on the number and vitality of seeds produced by a flower when treated with its own pollen, or *self-fertilized*, and when treated with pollen from another flower of the same kind, or *cross-fertilized*.[2]

197. *Wind-Fertilized Flowers.*[3]—It has already been mentioned (§ 189), that some pollen is dry and powdery, and other kinds are more or less sticky. Pollen of the dusty sort is light, and therefore adapted to be blown about by the wind. Any one who has been much in cornfields after the corn has "tasseled" has noticed the pale yellow dusty pollen which flies about when a cornstalk is jostled, and which collects in considerable quantities on the blades of the leaves. Corn is monœcious, but fertilization is best accomplished by pollen blown from the "tassel" (stamens) of one plant being carried to the "silk" (pistils) of another plant. This is well shown by the fact, familiar to every observing farmer's boy, that solitary cornstalks, such as often grow very luxuriantly in an unused barnyard or similar locality, bear very imperfect

[1] See Darwin's *Cross and Self-Fertilization in the Vegetable Kingdom* (especially Chapters I and II).

[2] On dispersion of pollen see Kerner and Oliver, vol. II, 129–287.

[3] See Miss Newell's *Botany Reader*, Part II, Chapter VII.

ears or none at all. The common ragweed, another monœcious plant, is remarkable for the great quantities of pollen which shake off it on to the shoes or clothes of the passer-by, and it is wind-fertilized. So, too, are the monœcious pines, and these produce so much pollen that it has been mistaken for showers of sulphur, falling often at long distances from the woods where it was produced. The pistil of wind-fertilized flowers is often feathery and thus adapted to catch flying pollen-grains (Fig. 143). Other characteristics of such flowers are the inconspicuous character of their flowers, which are usually green or greenish, the absence of odor and of nectar, the regularity of the corolla, and the appearance of the flowers before the leaves or their occurrence on stalks raised above the leaves.

FIG. 143. — Pistil of a Grass.

a, ovary; *b*, feathery stigma, adapted for wind-fertilization.

Pollen is, in the case of a few aquatic plants, carried from flower to flower by the water on which it floats.

198. *Insect-Fertilized Flowers.* — Most plants which require cross-fertilization depend upon insects as pollen-carriers,[1] and it may be stated as a general fact that the showy colors and markings of flowers and their odors, all serve as so many advertisements of the nectar (commonly but wrongly called honey), or of the nourishing pollen which the flower has to offer to insect-visitors.

Many insects depend mainly or wholly upon the nectar and the pollen of flowers for their food. Such insects usually visit during the day only one kind of flower, and therefore carry but one kind of pollen. Going straight from one flower to another with this, they evidently waste far less pollen than the wind or water must waste. It is therefore clearly advantageous to flowers to develop such adaptations as fit

[1] A few are fertilized by snails; many more by humming-birds and other birds.

them to attract insect-visitors, and to give pollen to the latter and receive it from them.

199. *Pollen-Carrying Apparatus of Insects.*[1] — Ants and many beetles which visit flowers have smooth bodies, to which little pollen adheres, so that their visits are often of little value to the flower, but many beetles, all butterflies and moths and most bees have bodies roughened with scales or hairs so as to hold a good deal of pollen entangled. In the common honey-bee (and in many other kinds) the greater part of the insect is hairy, and there are special collecting baskets, formed by bristle-like hairs, on the hind-legs, Fig. 144. It is easy to see the load of pollen accumulated in these baskets, after such a bee has visited several flowers. Of course the pollen which the bee packs in the baskets and carries off to the hive, to be stored for food, is of no use in fertilization. In fact such pollen is in one sense entirely wasted. But since such bees as have these collecting baskets are the most industrious visitors to flowers, they accomplish an immense share of the work of fertilization by means of the pollen-grains which stick to their hairy coats.

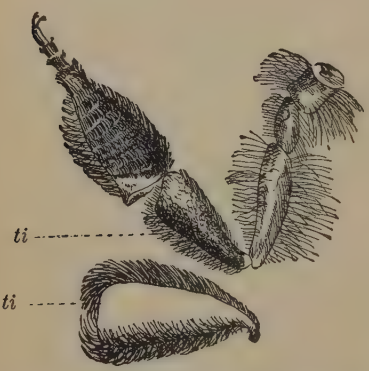


FIG. 144. — Right Hind-Leg of a Honey-Bee. (Seen from behind and within.)
ti (below), the tibia seen from the outside, showing the collecting basket, formed of stiff hairs.

200. *Nectar and Nectaries.* — Nectar is a sweet liquid which flowers secrete for the purpose of attracting insects. After partial digestion in the crop of the bee, nectar becomes

[1] See Müller's *Fertilization of Flowers*, Part II.

honey. Those flowers which secrete nectar do so by means of *nectar-glands*, small organs whose structure is something like that of the stigma, situated usually near the base of the flower, as shown in Fig. 145. Sometimes the nectar clings in droplets to the surface of the nectar-glands; sometimes it is stored in little cavities or pouches called *nectaries*. The pouches at the bases of columbine petals are among the most familiar of nectaries.

201. *Odors of Flowers.* — The acuteness of the sense of smell among insects is a familiar fact. Flies buzz about the wire netting which covers a piece of fresh meat or a dish of syrup, and bees, wasps, and hornets will fairly besiege the window-screens of a kitchen where preserving is going on. Many plants find it possible to attract as many insect-visitors as they need without giving off any scent, but small flowers, like the mignonette, and night-blooming ones, like the four-o'-clock and the evening primrose, are sweet-scented to attract night-flying moths. It is interesting to observe that the majority of the flowers which bloom at night are white, and that they are much more generally sweet-scented than flowers which bloom during the day. A few flowers are carrion-scented (and purplish or brownish colored) to attract flies.

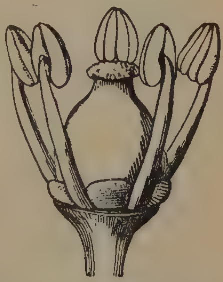


FIG. 145. — Stamens and Pistil of the Grape (magnified), with a nectar-gland between each pair of stamens.

202. *Colors of Flowers.* — Flowers which are of any other color than green display their colors to attract insects, or occasionally birds. The principal color of the flower is most frequently due to showy petals, sometimes, as in the marsh marigold, it belongs to the sepals, and not infrequently, as in some cornels and Euphorbias, the involucre is more brilliant and conspicuous than any part of the flower strictly so-called.

Different kinds of insects are especially attracted by different colors. In general, dull yellow, brownish or dark purple flowers, especially if small, seem to depend largely on the visits of flies. Red, violet, and blue are the colors by which bees and butterflies are most readily enticed. The power of bees to distinguish colors has been shown by a most interesting set of experiments in which daubs of honey were put on slips of glass laid on separate pieces of paper, each of a different color, and exposed where bees would find them.[1]

203. *Nectar Guides.* — In a large number of cases the petals of flowers show decided stripes or rows of spots, of a color different from that of most of the petal. These commonly lead toward the nectaries, and there is no doubt that such markings point out to insect-visitors the way to the nectaries. Following this course, the insect not only secures the nectar which he seeks, but perhaps leaves pollen on the stigma and becomes dusted with new pollen which he carries to another flower.

204. *Facilities for Insect Visits.* — Regular polypetalous flowers have no special adaptations to make them singly accessible to insects, but lie open to all comers. They do, however, make themselves much more attractive and afford especial inducements in the matter of saving time to flower-frequenting insects by being grouped. This purpose is undoubtedly served by dense flower-clusters, especially by heads like those of the clovers and by the peculiar form of head found in so-called compound flowers, like the sunflower and the bachelor's button (Fig. 165). In many such clusters the flowers are specialized, some as in Fig. 110, carrying a showy strap-shaped corolla, to serve as an advertisement of the nectar and pollen contained in the inconspicuous tubular

[1] See Lubbock's *Flowers, Fruits, and Leaves*, Chapter I. On the general subject of colors and odors in relation to insects, see Müller's *Fertilization of Flowers*, Part IV.

flowers. Irregular flowers probably always are more or less adapted to particular insect (or other) visitors. The adaptations are so numerous that many volumes could be filled with a description of them;—here only a very few of the simpler ones will be pointed out. Where there is a drooping lower petal (or, in the case of a gamopetalous corolla, a lower lip), this serves as a perch upon which flying insects may alight and stand while they explore the flower, as the beetle is doing in Fig. 146. In Fig. 147 one bumble-bee stands with his legs partially encircling the lower lip of the dead nettle flower, while another perches on the sort of grating made by the stamens of the horse-chestnut flower. The honey-bee entering the violet clings to the beautifully bearded portion of the two lateral petals, while it sucks the nectar from the *spur* beneath.

FIG. 146.—A Beetle on the Flower of the Twayblade. (Enlarged four times.)

FIG. 147.—Bees visiting Flowers.

At the left a bumble-bee (European) on the flower of the dead nettle; above a similar bee in the flower of the horse-chestnut; below. a honey-bee in the flower of a violet.

205. *Protection of Pollen from Unwelcome Visitors.* —It is usually desirable for the flower to prevent the entrance of small creeping insects, such as ants, which carry little pollen and eat a relatively large amount of it. The means adopted to secure this result are many and curious. In some plants, as the common catchfly, there is a sticky ring about the peduncle, some distance below the flowers, and this forms an effectual barrier against ants and like insects. Very frequently the calyx-tube is covered with hairs, which are sometimes sticky, as in Fig. 148, I, II, and VII. How these thickets of hairs may appear to a very small insect can perhaps be more easily realized by looking at the considerably magnified view of the hairs from the outer surface of mullein petals, shown in Fig. 149.[1]

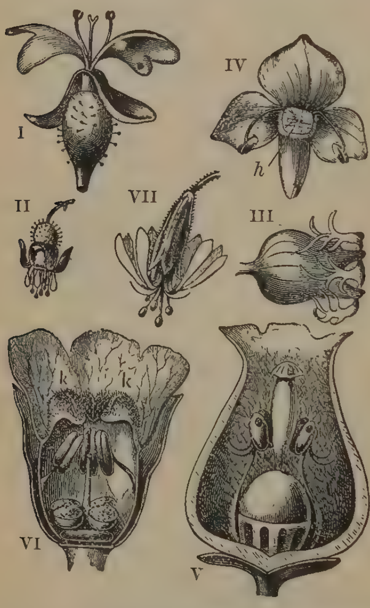


FIG. 148.—Flowers protected from Unwelcome Visitors.

I, enchanter's nightshade, magnified five times; II, gooseberry, natural size; III, tellima, magnified two times; IV, speedwell, magnified four times; V, bearberry, magnified six times; VI, hound's-tongue, magnified four times; VII, nodding campion, natural size, at midnight.

Sometimes the recurved petals or divisions of the corolla stand in the way of creeping insects, as in III and VII. In other cases the throat of the corolla is much narrowed, as in V, or closed

[1] On protection of pollen see Kerner and Oliver, vol. II, pp. 95–109.

by hairs, *h* in IV, or by appendages, *k* in VI. Those flowers which have one or more sepals or petals prolonged into spurs, like the nasturtium and the columbine, are inaccessible to most insects except those which have a tongue, or a sucking-

Fig. 149. — Branching Hairs from the Outside of the Corolla of the Common Mullein (magnified).
***dr*, a gland.**

tube long enough to reach to the nectary at the bottom of the spur. The large sphinx moth, shown in Fig. 150, which is a common visitor to the flowers of the evening primrose, is an

Fig. 150. — A Sphinx Moth, with a Long Sucking-Tube.

example of an insect especially adapted to reach deep into long tubular flowers.

A little search among flowers, such as those of the columbine or the foxglove, will usually disclose many which have had the corolla bitten through by bees, which are unable to get at the nectar by fair means and so steal it.

206. *Bird-Fertilized Flowers.* — Some flowers with very long tubular corollas depend entirely upon birds to carry their pollen for them. Among garden flowers the gladiolus, the scarlet salvia and the trumpet honeysuckle are largely dependent upon humming-birds for their fertilization. The

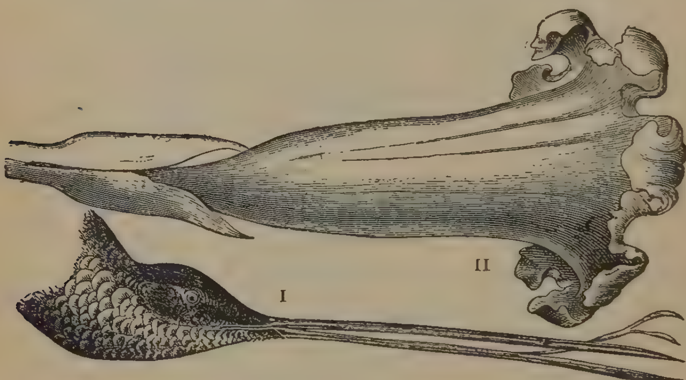


FIG. 151. — Flower-Frequenting Bird, with a Flower.
I, head of a sword-beak ; II, a datura flower, visited by it. (Both two-thirds natural size.)

wild balsam or jewel-weed and the trumpet-creeper are also favorite flowers of the humming-bird. In Fig. 151 the head of a flower-visiting bird and a flower frequented by it are shown.

207. *Prevention of Self-Fertilization.* — Diœcious flowers are of course quite incapable of self-fertilization. Pistillate monœcious flowers may be fertilized by staminate ones on the same plant, but this does not secure so good seed as is secured by having pollen brought to the pistil from a different plant.

In perfect flowers self-fertilization would commonly occur unless it were prevented by the action of the essential organs or by something in the structure of the flower. In reality flowers which at first sight would appear to be designed to secure self-fertilization are almost or quite incapable of it. Frequently the pollen from another plant prevails over that which the flower may shed on its own pistil, so that when both kinds are placed on the stigma at the same time it is the foreign pollen which causes fertilization. But apart from this fact, there are several means of insuring the presence of foreign pollen, and only that, upon the stigma, just when it is mature enough to receive pollen tubes.

FIG. 152. — Flower of Clerodendron in Two Stages.

In the upper figure (earlier stage) the stamens are mature, while the pistil is still undeveloped and bent to one side. In the lower figure (later stage) the stamens have withered and the stigmas have separated, ready for the reception of pollen.

208. *Stamens and Pistils maturing at Different Times.* — If the stamens mature at a different time from the pistils, self-fertilization is as effectually prevented as though the plant were diœcious. This unequal maturing or *dichogamy* occurs in many kinds of flowers. In some, the figwort and the common plantain, for example, the pistil develops before the stamens, but usually the reverse is the case. The *Clerodendron*, a tropical African flower, illustrates in a most striking way the development of stamens before the pistil. The insect-visitor, on its way to the nectary, can hardly fail to brush against the protruding stamens of the flower in its

earlier stage (above), but it cannot deposit any pollen on the stigmas which are unripe, shut together and tucked aside, out of reach. On flying to a flower in the later stage the pollen

FIG. 153.—Provisions for Cross-Fertilization in the High Mallow.

I, essential organs as found in the bud; II, same in the staminate stage, the anthers discharging pollen, pistils immature; III, intermediate stage, *stig*, the united stigmas; IV, pistillate stage, the stigmas separated, stamens withered.

just acquired will be lodged on the prominent stigmas and thus produce the desired cross-fertilization.

FIG. 154.—Stamens and Pistils of Round-Leafed Mallow (the stigmas curled round among the stamens to admit of self-fertilization).

Closely related flowers often differ in their plan of fertilization. The high mallow, a plant cultivated for its purplish flowers, which has run wild to some extent, is admirably adapted to secure cross-fertilization with its own pollen, since when its stamens are shedding pollen, as in Fig. 153, II, the pistils are incapable of receiving it, while when the pistils are mature, as at IV, the stamens are quite withered. In the common low mallow of our door-yards and waysides, insect fertilization may occur, but if it does not the curling stigmas finally come in contact with

the projecting stamens and receive pollen from them, as is indicated in Fig. 154.

209. *Movements of Floral Organs to aid in Fertilization.*— Besides the slow movements which the stamens and pistil make in such cases as those of the *Clerodendron* and the mallow, already described, the parts of the flower often admit of considerable and rather quick movements to assist the insect-visitor to become dusted or smeared with pollen.

In some flowers whose stamens perform rapid movements when an insect enters, it is easy to see how directly useful the motion of the stamens is in securing cross-fertilization.

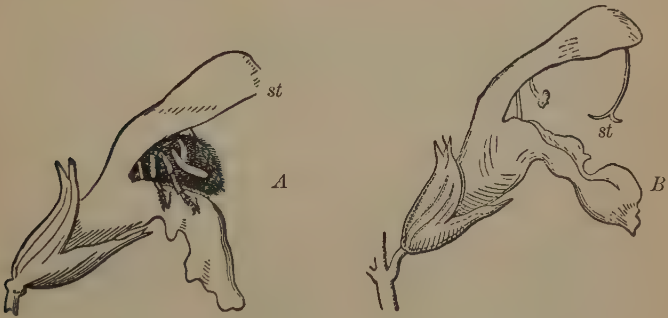


FIG. 155.—Two Flowers of Common Sage, one of them visited by a bee.

The stamens of the laurel, *Kalmia*, throw little masses of pollen, with a quick jerk, against the body of the visiting insect. Barberry stamens spring up against the visitor and dust him with pollen. The common garden sage matures its anthers earlier than its stigmas. In Fig. 155, *A*, the young flower is seen, visited by a bee, and one anther is shown pressed closely against the side of the bee's abdomen. The stigma *st* is hidden within the upper lip of the corolla. In *B*, an older flower, the anthers have withered and the stigma is now lowered so as to brush against the body of any

bee which may enter. A little study of Fig. 156 will make clear the way in which the anthers are hinged, so that a bee striking the empty or barren anther-lobes *a* knocks the pollen-

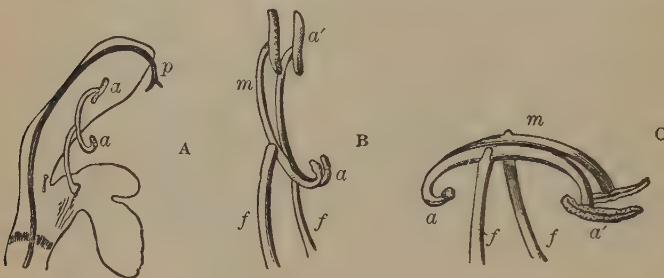


FIG. 156.—Flower and Stamens of Common Sage.

A, *p*, stigma; *a*, anthers. B, the two stamens in ordinary position; *f*, filaments; *m*, connective (joining anther-cells); *a*, *a*, anther-cells. C, the anthers and connectives bent into a horizontal position by an insect pushing against *a*.

bearing lobes *a′* into a horizontal position, so that they will lie closely pressed against either side of its abdomen.

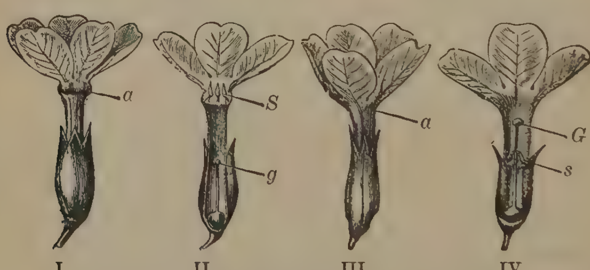


FIG. 157.—Dimorphous Flowers of the Primrose.

I, II, short-styled form; III, IV, long-styled form, natural size; *a*, throat of the corolla; *S*, *s*, stamens; *G*, *g*, styles.

210. *Flowers with Stamens and Pistils each of Two Lengths.*—The flowers of bluets, partridge-berry, the primroses and a few other common plants secure cross-fertilization by hav-

ing essential organs of two forms, Fig. 157. Such flowers are said to be *dimorphous* (*of-two-forms*). In the short-styled flowers, I, II, the anthers are borne at the top of the corolla tube *a*, *S*, and the stigma, *g*, stands about half-way up the tube. In the long-styled flowers, III, IV, the stigma *G* is at the top of the tube and the anthers, *S*, are borne about half-way up. An insect, pressing its head into the throat of the corolla of I or II would become dusted with pollen which would be brushed off on the stigma of a flower like III or IV. On leaving a long-styled flower, IV, the bee's tongue would be dusted over with pollen, some of which would necessarily be rubbed off on the stigma of the next short-styled flower that was visited. Cross-fertilization is insured, since all the flowers on a plant are of one kind, either long-styled or short-styled, and since the pollen is of two sorts, each kind sterile on the stigma of any flower of similar form to that from which it came.

Trimorphous flowers, with long, medium, and short styles, are found in a species of loosestrife.[1]

211. *Studies in Insect Fertilization.* — The student cannot gather more than a very imperfect knowledge of the details of cross-fertilization in flowers without actually watching some of them as they grow, and observing their insect-visitors. If the latter are caught and dropped into a wide-mouthed stoppered bottle containing a bit of cotton saturated with chloroform, they will be painlessly killed and most of them may be identified by any one who is familiar with our common insects. The insects may be observed and classified in a general way into butterflies, moths, bees, flies, wasps, and beetles, without being captured or molested.

Whether these out-of-door studies are made or not, several flowers should be carefully examined and described as regards their arrangements for attracting and utilizing insect-visitors (or birds). The following list includes a considerable number of the most accessible flowers of spring and early summer, about which it is easy to get information from books.

[1] See Miss Newell's *Reader in Botany*, Part II, pp. 60–63.

List of Insect-Fertilized Flowers.[1]

I.

1. Flax	*Linum usitatissimum*	Müll.
2. Missouri currant	*Ribes aureum*	Müll.
3. Snowberry	*Symphoricarpus racemosus*	Müll.
4. Lilac	*Syringa Persica*	Müll.
5. Periwinkle	*Vinca minor*	Müll.
6. Mignonette	*Reseda odorata*	Müll.
7. Pansy	*Viola tricolor*	Müll.
8. Dead nettle	*Lamium album*	Lubbock.
9. Bleeding heart	*Dicentra* (*Diclytra*) *spectabilis*	Müll.
10. Columbine	*Aquilegia vulgaris*	Müll.
11. Monkshood	*Aconitum Napellus*	Müll.

II.

12. Larkspur	*Delphinium elatum, D. consolida*	Müll.
13. Herb Robert	*Geranium Robertianum*	Müll.
14. Pink	*Dianthus* (various species)	Müll.
15. Fireweed	*Epilobium angustifolium*	Gray.
16. Nasturtium	*Tropæolum majus*	Newell, Lubbock
17. Lily of the valley	*Convallaria majalis*	Müll.
18. Heal-all	*Brunella* (*Prunella*) *vulgaris*	Müll.
19. Ground ivy	*Nepeta Glechoma*	Müll., Newell.
20. Lousewort	*Pedicularis Canadensis*	Müll., Newell.
21. Snapdragon	*Antirrhinum majus*	Müll.
22. Iris	*Iris versicolor*	Newell.
23. Bellflower	*Campanula rapunculoides*	Müll.
24. Horse-chestnut	*Æsculus Hippocastanum*	Newell.

III.

25. Yarrow	*Achillea millefolium*	Müll.
26. Ox-eye daisy	*Chrysanthemum Leucanthemum*	Müll.
27. Dandelion	*Taraxacum officinale*	Müll., Newell.

[1] The plants in this list are arranged somewhat in the order of the complexity of their adaptations for insect fertilization, the simplest first. It would be well for each student to take up the study of the arrangements for the utilization of insect-visitors in several of the groups above, numbered with Roman numerals. The teacher will find explanations of the adaptations in the works cited by abbrevia-

List of Insect-Fertilized Flowers — *concluded.*

IV.

28. Barberry	*Berberis vulgaris*	Lubbock.
29. Mountain laurel . .	*Kalmia latifolia*	Gray.

V.

30. White clover . . .	*Trifolium repens*	Müll.
31. Red clover . . .	*Trifolium pratense*	Mull.
32. Locust	*Robinia Pseudacacia*	Gray.
33. Wistaria	*Wistaria Sinensis*	Gray.
34. Vetch	*Vicia cracca*	Müll.
35. Pea	*Pisum sativum*	Müll.
36. Bean	*Phaseolus vulgaris*	Gray.
37. Ground-nut . . .	*Apios tuberosa*	Gray.

VI.

38. Partridge-berry . .	*Mitchella repens*	Gray.
39. Primrose	*Primula grandiflora*, *P. officinalis*	Lubbock.
40. Loosestrife . . .	*Lythrum Salicaria*	Gray.

VII.

41. Milkweed	*Asclepias Cornuti*	Müll., Newell.

VIII.

42. Lady's-slipper . .	*Cypripedium acaule*	Newell.

212. *Protection of Pollen from Rain.* — Pollen is very generally protected from being soaked and spoiled by rain or dew either by the natural position of the flower preventing rain from entering, as in the case with most gamopetalous, nodding flowers, or by changes in the position of the flower, and by its opening in sunny weather and closing at night or during

tions at the right. Müll. stands for Müller's *Fertilization of Flowers;* Lubbock, for *British Wild Flowers, Considered in Relation to Insects*; Gray, for Gray's *Structural Botany;* and Newell, for Miss Newell's *Outlines of Lessons in Botany,* Part II. Consult also Weed's *Ten New England Blossoms.*

rain. Sometimes the flower both changes its position and closes, as is the case with the herb Robert and the sweet scabious, Fig. 158. The adaptations of flowers to protect their pollen from being wetted can best be made out by actually examining the same flower in sunshine and during rain.

FIG. 158. — Protection of Pollen from Moisture.

I, herb Robert in sunny weather ; II, sweet scabious in sunny weather ; III, sweet scabious during rain ; IV, herb Robert during rain.

213. *Detailed Study of Flowers.* — Now that the student has learned something of the adaptations of flowers to insect-visitors, he is able to carry on such studies as those of Chapter XV in more detail. After making a careful examination of the flower as a whole and of its parts,

in various stages of maturity, he may investigate its adaptations for insect fertilization and its mode of protecting its pollen from creeping insects and from rain. It will be particularly interesting to compare the various degrees of perfection with which closely related flowers attain these results. Several flowers should be worked out pretty fully and the results of the examination of each recorded in a written account and a series of sketches. Out of the many possible studies of this kind the following are suggested:

The flower of the pea, the bean, or the locust, consulting Figs. 159, 160, 161.

FIG. 159. — Sweet Pea, Flower, Young Fruit, and Leaf.

FIG. 160. — I, Diagram of Flower of Sweet Pea. II, Vertical Section of Flower (magnified). III, Calyx (magnified).

The flower of the peach, the plum, or the rose, consulting Figs. 162 and 163.

FIG. 161.—I, Stamens and Pistil of Sweet Pea (magnified). II, Fruit. III, Part of Fruit, showing one seed.

FIG. 162.—Flower of Pear.

FIG. 163.—I, Vertical section of Flower of Pear. II, Ovary, transverse section. III, Entire Seed (magnified). IV, Seed, vertical section (magnified).

The flower of the ox-eye daisy, or the dandelion, consulting Figs, 110, 131, 164, 165, 166

FIG. 164. — Flower-Cluster of Bachelor's Button (*Centaurea Cyanus*).

The flower of the crocus, the blue-eyed grass, or the iris, consulting Figs. 167 and 168.[1]

[1] For descriptions and illustrations that will aid in the work of this section the teacher is referred to Gray's *Structural Botany*, Gray's *Field, Forest, and Garden Botany*, Le Maout and Decaisne's *Traité Général de Botanique*, and Miss Newell's *Outlines of Lessons in Botany*, Part II.

FIG. 165. — Bachelor's Button.

I, a tubular flower (magnified), *anth*, the united anthers ; II, fruit (magnified) ; III, fruit, vertical section (magnified) ; IV, a neutral ray-flower ;[1] V, ring of anthers.

FIG. 166. — Bachelor's Button.

I, vertical section of the receptacle ; II, style and forked stigma (magnified) ; III, corolla, united anthers and stigma (magnified) ; IV, pistil (magnified), *pap*, pappus, *ach*, achenium ; V, tubular flower cut vertically (magnified), showing anther-tube, traversed by the style.

[1] This is not precisely homologous with the ray-flowers of Helianthus and most rayed Compositæ, but is an enlarged and conspicuous tubular flower.

I II III

FIG. 167. — Iris.

I, flower ; II, seed, longitudinal section ; III, flower with limb of perianth removed ; *stig*, stigma, *ov*, ovary.

I FIG. 168. — Iris. III

I, flower, longitudinal section, *ov*, ovary ; II, diagram, showing stigmas opposite the stamens ; III, capsule, splitting between the partitions.

CHAPTER XIX.

The Study of Typical Fruits.

214. *A Berry, the Tomato.*[1] — Study the external form of the tomato, and make a sketch of it, showing the persistent calyx and peduncle.

Cut a cross-section at about the middle of the tomato. Note the thickness of the epidermis (peel off a strip) and of the wall of the ovary. Note the number, size, form, and contents of the cells of the ovary. Observe the thickness and texture of the partitions between the cells. Sketch.

Note the attachments of the seeds to the placentas and the gelatinous, slippery coating of each seed. Rub off this coating and then note the wing-like margin around the seed.

The tomato is a typical berry, but its structure presents fewer points of interest than are found in some other fruits of the same general character, so the student will do well to spend a little more time on the examination of such fruits as the orange or the lemon.

215. *A Hesperidium, the Lemon.* — Procure a large lemon which is not withered, if possible one which still shows the remains of the calyx at the base of the fruit.

Note the color, general shape, surface, remains of calyx, knob at portion formerly occupied by the stigma. Sketch the fruit about natural size. Examine the pitted surface of the rind with the magnifying-glass and sketch it. Remove the bit of stem and dried-up calyx from the base of the fruit; observe, above the calyx, the knob or *disk* on which the pistil stood. Note with the magnifying glass and count the minute whitish raised knobs at the bottom of the saucer-shaped depression left by the removal of the disk.

Make a transverse section of the lemon, not more than a fifth of the way down from the stigma end and note:

(1) The thick skin, pale yellow near the outside, white within.

(2) The more or less wedge-shaped divisions containing the juicy pulp of the fruit. These are the matured cells of the ovary; count these.

(3) The thin partitions between the cells.

[1] Fresh tomatoes, not too ripe, are to be used, or those which have been kept over from the previous summer in formalin solution. The very smallest varieties, such as are often sold for preserving, are as good for study as the larger kinds.

(4) The central column or axis of white pithy tissue.

(5) The location and attachment of any seeds that may be encountered in the section.

Make a sketch to illustrate these points, comparing it with Fig. 181.

Study the section with the magnifying glass and note the little spherical reservoirs near the outer part of the skin, which contain the oil of lemon which gives to lemon-peel its characteristic smell and taste. Cut with the razor a thin slice from the surface of the lemon-peel, some distance below the section, and at once examine the freshly cut surface with a magnifying glass to see the reservoirs, still containing oil, which, however, soon evaporates. On the cut surface of the pulp (in the original cross-section) note the tubes in which the juice is contained. These tubes are not cells, but their walls are built of cells. Cut a fresh section across the lemon, about midway of its length and sketch it, bringing out the same points which were shown in the previous one. The fact that the number of ovary cells in the fruit corresponds with the number of minute knobs in the depression at its base is due to the fact that these knobs mark the points at which fibro-vascular bundles passed from the peduncle into the cells of the fruit, carrying the sap by which the growth of the latter was maintained.

Note the toughness and thickness of the seed-coats. Taste the kernel of the seed.

Cut a very thin slice from the surface of the skin, mount in water, and examine with a medium power of the microscope. Sketch the cellular structure shown and compare it with the sketch of the corky layer of the bark of the potato tuber.

Of what use to the fruit is a corky layer in the skin? (See § 230 for further questions.)

216. *A Legume, the Bean-Pod.*[1] — Lay the pod flat on the table and make a sketch of it, about natural size. Label *stigma*, *style*, *ovary*, *calyx*, *peduncle*.

Make a longitudinal section of the pod, at right angles to the plane in which it lay as first sketched, and make a sketch of the section, showing the partially developed seeds, the cavities in which they lie, and the solid portion of the pod between each bean and the next.

Split another pod, so as to leave all the beans lying undisturbed on one-half of it and sketch that half, showing the beans lying in their

[1] Any species of bean (*Phaseolus*) will answer for this study. Specimens in the condition known at the markets as "shell-beans" would be best, but these are not obtainable in spring. Ordinary "string-beans" will do.

natural position and the *funiculus* or stalk by which each is attached to the *placenta ;* compare Fig. 176.

Make a cross-section of another pod, through one of the beans, sketch the section and label the placenta (formed by the united edges of the pistil leaf), and the midrib of the pistil leaf.

Break off sections of the pod and determine, by observing where the most stringy portions are found, where the fibro-vascular bundles are most numerous.

Examine some ripe pods of the preceding year,[1] and notice where the *dehiscence*, or splitting open of the pods occurs, whether down the placental edge, *ventral suture*, the other edge, *dorsal suture*, or both.

217. *An Akene, the Fruit of Dock.* — Hold in the forceps a ripe fruit of any of the common kinds of dock,[2] and examine with the magnifying-glass. Note the three dry, veiny, membranaceous sepals by which the fruit is enclosed. On the outside of one or more of the sepals is found a tubercle or thickened appendage which looks like a little seed or grain. No use is known for this.

Of what use are the sepals, after drying up ? Why do the fruits cling to the plant long after ripening ?

Carefully remove the sepals and examine the fruit within them. What is its color, size, and shape ? Make a sketch of it as seen with the magnifying glass. Note the three tufted stigmas, attached by slender threads to the apex of the fruit. What does their tufted shape indicate ?

What evidence is there that this seed-like fruit is not really a seed ?

Make a cross-section of a fruit and notice whether the wall of the ovary can be seen, distinct from the seed coats. Compare the dock-fruit in this respect with the fruit of the anemone, shown in Fig. 169. Such a fruit as either of these is called an *akene.*

[1] Which may be passed round for that purpose. They should have been saved and dried the preceding autumn.

[2] *Rumex crispus*, *R. obtusifolius*, or *R. verticillatus*. This should have been gathered and dried the preceding summer.

CHAPTER XX.

The Fruit.[1]

218. *What Constitutes a Fruit.* — It is not easy to make a short and simple definition of what botanists mean by the term *fruit.* It has very little to do with the popular use of the word. Briefly stated, the definition may be given as follows: *The fruit consists of the matured ovary, together with any intimately connected parts.* Botanically speaking, the bur of beggar's ticks, Fig. 179, the three-cornered grain of buckwheat, or such true grains as wheat and oats are as much fruits as is an apple or a peach.

I II

FIG. 169. — Fruit of Wood Anemone.

I, akene cut vertically; II, whole akene.

The style or stigma sometimes remains as an important part of the fruit in the shape of a hook, as in the common hooked crowfoot; or in the shape of a plumed appendage, as in the virgin's bower, often called wild hops. The calyx may develop hooks, as in the agrimony or plumes, as in the thistle, the dandelion, lettuce, and many other familiar plants. In the apple, pear, and very many berries, the calyx becomes enlarged and pulpy, often constituting the main bulk of the mature fruit. The receptacle not infrequently, as in the apple, forms a more or less important part of the fruit.

219. *The Akene.* — The one-celled and one-seeded pistils of the buttercup, strawberry, and many other flowers ripen into a little fruit called an akene, Fig. 169. Such fruits, from their small size, their dry consistency, and the fact that

[1] See Gray's *Structural Botany*, Chapter VII, also Kerner and Oliver, vol. II, pp. 427–438.

they never open, are usually taken by those who are not botanists for seeds.

In the group of plants to which the daisy, the sunflower and the dandelion belong, the akenes consist of the ovary and the adherent calyx-tube. The limb of the calyx is borne on the summit of many akenes, sometimes in the form of teeth, sometimes as a tuft of hairs or bristles, Fig. 174.

FIG. 170.—Chestnut, a Single Fruit.

220. *The Grain.*—Grains, such as corn, wheat, oats, barley, rice and so on have the interior of the ovary completely filled by the seed, and the seed-coats and the wall of the ovary are firmly united, as shown in Fig. 9.

221. *The Nut.*—A nut, Fig. 170, is larger than an akene, usually has a harder shell and commonly contains a seed which springs from a single ovule of one cell of a compound ovary, which develops at the expense of all the other ovules. The chestnut-bur is a kind of involucre, and so is the acorn-cup. The name nut is often incorrectly applied in popular language, for example, the so-called Brazil-nut is really a large seed with a very hard testa.

FIG. 171.—Group of Follicles and a Single Follicle of the Monkshood.

222. *Indehiscent and Dehiscent Fruits.*—All of the fruits so far considered in the present chapter are indehiscent, that is, they remain closed after ripening. Dehiscent fruits when ripe open in order to discharge their seeds. The three classes which immediately follow belong to this division.

223. *The Follicle.*—One-celled, simple pistils, like those

of the marsh marigold, the columbine, and a good many other plants, often produce a fruit which dehisces along a single suture, usually the ventral one. Such a fruit is called a *follicle*, Fig. 171.

224. *The Legume.* — A legume is a one-celled pod, formed by the maturing of a simple pistil, which dehisces along both of its sutures, as already seen in the case of the bean pod, and illustrated in Fig. 176.

225. *The Capsule.* — The dehiscent fruit formed by the

FIG. 172. — Winged Fruits.
I, elm; II, maple.

ripening of a compound pistil is called a *capsule*. Such a fruit may be one-celled, as in the linear pod of the celandine, Fig. 176, or several-celled, as in the fruit of the poppy, the morning-glory and the Jamestown weed, Fig. 176.

226. *Dry Fruits and Fleshy Fruits.* — In all the cases discussed or described in §§ 213–219 the wall of the ovary (and the adherent calyx when present) ripen into tissues which are somewhat hard and dry. Often, however, these parts become developed into a juicy or fleshy mass by which

the seed is surrounded. Hence a general division of fruits into *dry fruits* and *fleshy fruits.*

227. *Winged or Tufted Fruits and Seeds.* — The fruits of the ash, box-elder, elm, maple, Fig. 172, and many other trees are provided with an expanded membranous wing. Some seeds, as those of the catalpa and the trumpet-creeper are similarly appendaged. The fruits of the dandelion, the thistle, the fleabane, Fig. 174, and many other plants of the group to which these belong, and the seeds of the willow, the milkweed, the willow-herb, Fig. 175, and other plants, bear a tuft of hairs, sometimes silky and in other cases plumed or feathery.

The student should be able from his own observations on the falling fruits of some of the trees and other plants above mentioned to answer some such questions as the following:

FIG. 173.—Fruit-Cluster of Linden; peduncle joined to the bract, forming a wing.

What is the use of the wing-like appendages? of the tufts of hairs?

Which set of contrivances seems to be the more successful of the two in securing this object?

What particular plant of the ones available for study seems to have attained this object most perfectly?

What is one reason why many plants with tufted seeds, such as the thistle and the dandelion, are extremely troublesome weeds?

A few simple experiments, easily devised by the student, may help him to find answers to the questions above given.[1]

[1] See Kerner and Oliver, vol. II, pp. 833–875.

It is an interesting and well-established fact that a good many birds, especially bluejays, bury large numbers of acorns and nuts which they intend to consume later, and that they leave a considerable portion of these deposits untouched. In this way large numbers of trees are annually planted.

FIG. 174. — Tufted Fruit of Fleabane.

228. *Burs.* — A large class of fruits is characterized by the presence of hooks on the outer surface. These are sometimes outgrowths from the ovary, sometimes from the calyx, sometimes from an involucre. Their office is to attach the fruit to the hair or fur of passing animals or to the clothing of people who come in contact with it. Often, as in cleavers, Fig. 177, the hooks are comparatively weak, but in other cases, as in the cocklebur, Figs. 178, 179, and still more in the Martynia, the fruit of which in the green condition is

I II

FIG. 175. — Seeds with Tufts of Hair.
I, milkweed; II, willow-herb.

much used for pickles, the hooks are exceedingly strong. Cockleburs can hardly be removed from the tails of horses and cattle, into which they have become matted, without cutting out all the hairs to which they are fastened.

The usefulness of burs to the plant which produces them is evident enough.

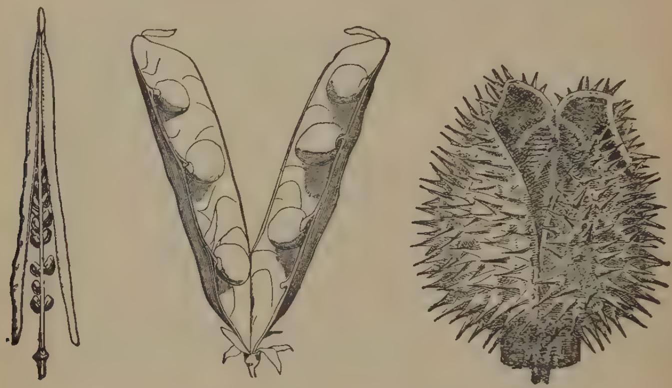


Fig. 176. — Dehiscent Fruits.
I, linear capsule of celandine; II, pod of pea; III, capsule of thorn-apple or Jamestown weed.

Fig. 177. — Adhesive Fruits.
At left, hound's-tongue; at right, cleavers.

Why do bur-bearing plants often carry their fruit until late winter or early spring?

What reason can be given for the fact that the burdock, the cocklebur, the beggar-ticks, the hound's-tongue, and many other common burs, are among the most persistent of weeds?

229. *Explosive Fruits.* — Some dry fruits burst open when ripe in such a way as to throw their seeds violently about. Interesting studies may be made of this section in the common blue violet, the pansy, the wild balsam, the garden balsam, the crane's-bill, the herb Robert, the witch hazel, and some other common plants. The capsule of the South American sand-box tree bursts open when thoroughly dry with a noise like that of a pistol-shot.

How are plants benefited by the explosion of the fruit?[1]

FIG. 178. — A Cocklebur, slightly enlarged.

230. *Uses of Fruits to the Plant.* — Those portions of the fruit which surround the seeds serve to enclose the ovules during their period of ripening, and to protect them from drying up or from other injuries. Other kinds of service rendered by the coatings or appendages of the fruit may have been suggested by the questions asked in some of the preceding sections.

Besides the *dry fruits* of which some of the principal kinds have been mentioned, there are many kinds of *stone fruits and fleshy fruits*, §§ 225–231. Of these the great majority are eatable by man or some of the lower animals, and oftentimes the amount of sugar and other food material which they contain is very great. It is a well recognized principle of botany, and of zoölogy as well, that plants and animals do not make outlays for the benefit of other species. Evidently the pulp of fruits is not to be consumed or used as food by the plant itself or (in general) by its seeds. It is worth

[1] See Lubbock's *Flowers, Fruits, and Leaves*, Chapter III.

while, therefore, for the student to ask himself some such questions as these :[1]

(1) Why is the pulp of so many fruits eatable?

(2) Why are the seeds of many pulpy fruits bitter or otherwise unpleasantly flavored, as in the orange?

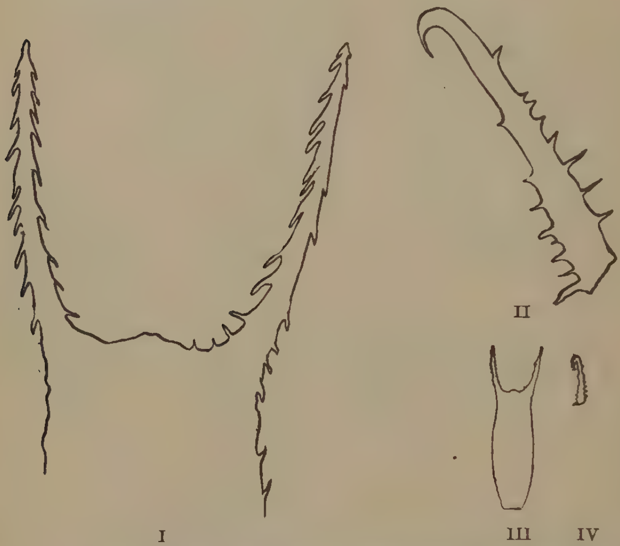


FIG. 179. — I, Barbed Points from Fruit of Beggar's Ticks, magnified eleven times. II, Hook of Cocklebur, magnified eleven times; III, Beggar's Ticks Fruit, natural size; IV, Cocklebur Hook, natural size.

(3) Why are the seeds or the layers surrounding the seeds of many pulpy fruits too hard to be chewed, as in the date and the peach?

(4) Why are the seeds of some pulpy fruits too small to be easily chewed, as in the fig and the currant?

(5) Account for the not infrequent presence of currant

[1] See Kerner and Oliver, vol. II, pp. 442–450, and *Phytobiology* (second paper), by Prof. W. F. Ganong, Bulletin No. 13 of the New Brunswick Natural History Society, St. John, N. B.

bushes or asparagus plants in such localities as the forks of large trees, sometimes at a height of twenty, thirty or more feet above the ground.

Careful observation of the neighborhood of peach, plum, cherry, or apple trees at the season when the fruit is ripe and again during the following spring, and an examination into the distribution of wild apple or pear trees in pastures where they occur, will help the student who can make such observations to answer the preceding questions. So, too, would an examination of the habits of fruit-eating quadrupeds and of the crop and gizzard of fruit-eating birds during the season when the fruits upon which they feed are ripe.

231. *The Stone-Fruit.* — In the peach, apricot, plum, and cherry, the *pericarp* or wall of the ovary, during the process of ripening, becomes converted into two kinds of tissue, the outer portion pulpy and edible, the inner portion of almost stony hardness. In common language the hardened inner layer of the pericarp, enclosing the seed, is called the "stone," Fig. 180, hence the name *stone-fruits.*

FIG. 180. — Peach.
Longitudinal section of fruit.

232. *The Pome.* — The fruit of the apple, pear, and quince is called a *pome.* It consists of a several-celled ovary — the seeds and the tough membrane surrounding them in the "core," — enclosed by a fleshy, eatable portion which makes up the main bulk of the fruit and is formed from the much thickened calyx, with sometimes an enlarged receptacle.

233. *The Pepo or Gourd-Fruit.* — In the squash, pumpkin, melon, and cucumber, the ripened ovary together with the

thickened adherent calyx makes up a peculiar fruit (with a firm outer rind) known as the *pepo*. The relative bulk of enlarged calyx and of ovary in such fruits is not always the same.

How does the amount of material derived from fleshy and thickened placentæ in the squash compare with that in the watermelon?

234. *The Berry.* — The berry proper, such as the tomato, grape, persimmon, gooseberry, currant, and so on, consists of a rather thin-skinned one to several-celled fleshy ovary and its contents. In the first three cases above mentioned the calyx forms no part of the fruit, but it does in the last two, and in a great number of berries.

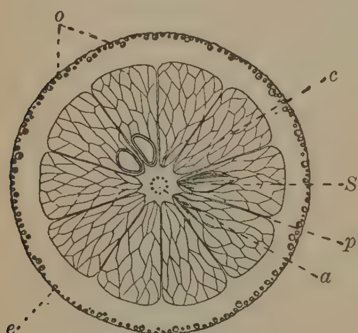


FIG. 181. — Cross-Section of an Orange.
a, axis of fruit with dots showing cut-off ends of fibro-vascular bundles; *p*, partition between cells of ovary; *S*, seed; *c*, cell of ovary, filled with a pulp composed of irregular tubes, full of juice; *o*, oil reservoirs near outer surface of rind; *e*, corky layer of epidermis.

The gourd-fruit and the *hesperidium*, such as the orange, Fig. 181, lemon, and lime, are merely decided modifications of the berry proper.

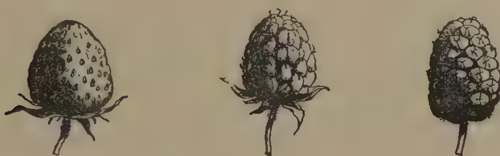
235. *Aggregate Fruits.* — The raspberry, blackberry, Fig. 182, and similar fruits consist of many carpels, each of which ripens into a part of a compound mass, which, for a time at least, clings to the receptacle. The whole is called an *aggregate fruit.*

To which one of the preceding classes does each unit of a blackberry or of a raspberry belong?

What is the most important difference in structure between a fully ripened raspberry and a blackberry?

236. *Accessory Fruits and Multiple Fruits.* — Not infrequently, as in the strawberry, Fig. 182, the main bulk of the fruit consists neither of the ripened ovary nor its appendages.

Examine with a magnifying glass the surface of a small, unripe strawberry,[1] then that of a ripe one, and finally a section of a ripe one, and decide where the separate fruits of the strawberry are found, what kind of fruits they are, and of what the main bulk of the strawberry consists.



I II III

FIG. 182. — I, Strawberry; II, Raspberry; III, Mulberry.

The fruits of two or more separate flowers may blend into a single mass, which is known as a *multiple fruit.* Perhaps the best known edible examples of this are the mulberry, Fig. 182, and the pineapple. The last-named fruit is an excellent instance of the seedless condition which not infrequently results from long-continued cultivation.

237. *Summary.* — The student may find it easier to retain what knowledge he has gained in regard to fruits if he copies the following synopsis of the classification of fruits,[2] gives an example of each kind, and in every case where it is possible to do so indicates briefly how the dispersion of the seed is secured.

[1] A few such berries, preserved in alcohol, or in formalin solution, will answer for an entire division.

[2] Suggested by Mr. Marcus L. Glazer.

- Fruits
  - Composition
    - Simple.
    - Aggregate.
    - Accessory.
    - Multiple.
  - Texture
    - Fleshy
      - Berry.
      - Pepo.
      - Pome.
    - Stone
      - Drupe, etc.
    - Dry
      - Akene.
      - Grain.
      - Nut.
      - Others.
  - Mode of Disseminating Seed
    - Indehiscent
      - Akene.
      - Grain.
      - Nut.
    - Dehiscent
      - Follicle.
      - Legume.
      - Capsule.

CHAPTER XXI.

The Struggle for Existence and the Survival of the Fittest.[1]

238. *Weeds.* — Any flowering plant which is troublesome to the farmer or gardener is commonly known as a weed. Though such plants are so annoying, from their tendency to crowd out others useful to man, they are of extreme interest to the botanist on account of this very hardiness. The principal characteristics of the most successful weeds are their ability to live in a variety of soils and exposures, their rapid growth, resistance to frost, drought, and dust, their unfitness for the food of most of the larger animals, in many cases their capacity to accomplish self-fertilization, in default of cross-fertilization, and their ability to produce many seeds and to secure their wide dispersal. Not every weed combines all of these characteristics. For instance, the velvet-leaf or butter-print[2] common in corn-fields, is very easily destroyed by frost; the pigweed and purslane are greedily eaten by pigs and the ragweed by some horses. The horse-radish does not usually produce any seeds.

It is a curious fact that many plants which have finally proved to be noxious weeds have been purposely introduced into the country. The fuller's teasel, melilot, horseradish, wild carrot, wild parsnip, tansy, ox-eye daisy, and field-garlic are only a few of the many examples of very troublesome weeds which were at first planted for use or for ornament.

[1] See Darwin's *Origin of Species*, Chapters III and IV.
[2] *Abutilon Avicennæ.*

239. *Study of Weeds.* — Select two or more out of the following list of weeds and report on the qualities which make them troublesome from the farmer's point of view (successful from their own).[1]

List of Weeds.[2]

1. Beggar's lice.*
2. Beggar's ticks.
3. Burdock.*
4. Buttercup.*
5. Butterweed.
6. Cocklebur.*
7. Charlock.*
8. Chicory.*
9. Chickweed.
10. Daisy, ox-eye.*
11. Dandelion.*
12. Dock.
13. Dog fennel.*
14. Fox-tail grass.*
15. Horse-nettle.
16. Jamestown weed.*
17. Mallow.*
18. Milkweed.
19. Nettle.
20. Pigweed.*
21. Plantain.*
22. Pokeberry.
23. Purslane.
24. Quick-grass.*
25. Ragweed.
26. Sandbur.
27. Smartweed.
28. Tansy.*
29. Thistle.*
30. Yarrow.

[1] This study will be of little value in city schools, since the plants should be examined as they grow. Specimens of the mature weed and of its fruits and seeds may be preserved by the teacher from one season to another for class use. Whole specimens of small plants, such as purslane, may be put into preservative fluid (Appendix). Ordinary weeds, such as ragweed, pigweed, etc., may be pressed and kept as roughly prepared herbarium specimens, while such very large plants as Jamestown weed, dock, etc., may be hung up by the roots and thus dried.

[2] The botanical names, as found in the last edition of Gray's Manual, are given below. Names marked in the list thus * are those of plants introduced from other countries, mostly from Europe.

1. Cynoglossum officinale.
2. Desmodium Canadense ; Bidens frondosa.
3. Arctium Lappa.
4. Ranunculus bulbosus.
5. Erigeron Canadensis.
6. Xanthium spinosum.
7. Brassica Sinapistrum.
8. Cichorium Intybus.
9. Stellaria media.
10. Chrysanthemum leucanthemum.
11. Taraxacum officinale.
12. Rumex crispus.
13. Anthemis Cotula.
14. Setaria glauca.
15. Solanum Carolinense.
16. Datura Stramonium.
17. Malva rotundifolia.
18. Asclepias Cornuti.
19. Urtica gracilis.
20. Chenopodium album ; Amarantus retroflexus.
21. Plantago major.
22. Phytolacca decandra.
23. Portulaca oleracea.
24. Agropyrum repens.
25. Ambrosia artemisiæfolia.
26. Cenchrus tribuloides.
27. Polygonum Hydropiper.
28. Tanacetum vulgare.
29. Cnicus lanceolatus ; Cnicus arvensis.
30. Achillea millefolium.

240. *Origin of Weeds.*[1] — By far the larger proportion of our weeds are not native to this country. Some have been brought from South America and from Asia, but most of the *introduced* kinds come from Europe. The importation of various kinds of grain and of garden-seeds mixed with seeds of European weeds will account for the presence of many of the latter among us. Others have been brought over in the ballast of vessels. Once landed, European weeds have succeeded in establishing themselves in so many cases because they were superior in vitality and in their power of reproduction to our native plants. This may not improbably be due to the fact that the vegetation of Europe and the neighboring portions of Asia, much of it consisting from very early times of plants of comparatively treeless plains, has for ages been habituated to grow in cultivated ground and to contend with the crops which are tilled there.

241. *Plant Life maintained under Difficulties.* — Plants usually have to encounter many obstacles to their growth or even to their bare existence. For every plant which succeeds in reaching maturity and producing a crop of spores or of seeds, there are hundreds or thousands of failures. It is easy to show by calculation in the case of any particular kind of plant, how small a proportion the seeds which live must bear to those which are destroyed. The common morning-glory (Ipomœa purpurea) is only a moderately prolific plant, producing, in an ordinary soil, somewhat more than 3,000 seeds.[2] If all these seeds were planted and grew, there would, of course, be 3,000 plants the second summer, sprung from the single parent-plant. Suppose each of these plants to bear as the parent did, and so on. Then there would be:

[1] See the article "Pertinacity and Predominance of Weeds," in *Scientific Papers of Asa Gray*, selected by C. S. Sargent, vol. II, pp. 234–242.

[2] Rather more than 3200 by actual count and estimation.

9,000,000 plants the third year,
27,000,000,000 plants the fourth year,
81,000,000,000,000 plants the fifth year,
243,000,000,000,000,000 plants the sixth year,
729,000,000,000,000,000,000 plants the seventh year.

It is not difficult to see that the offspring of a single morning-glory plant would, at this rate, soon actually cover the entire surface of the earth. The fact that morning-glories do not occupy any larger amount of territory than they do must therefore depend upon the fact that the immense majority of their seeds are not allowed to grow into mature plants.

242. *Importance of Dispersal of Seeds.* — It is clear that any means of securing the wide distribution of seeds is of vital importance in continuing and increasing the numbers of any kind of plant, since in this way destruction by over-crowding and starvation will be lessened.

A few of the means of transportation of seeds have been hinted at in §§ 227–230, but the cases are so numerous and varied that a special treatise might well be devoted to this subject alone.

Seeds are transported by the wind, by the water, by men and other animals, and (to short distances) by the explosive action of the capsules in which they mature, or by similar contrivances. A most valuable topic for study in late summer and autumn is that of the various devices for seed-carrying found in common plants.

Not only are small seeds and fruits, like those of the willow and thistle respectively, borne for long distances by the wind, but an entire flower-cluster may ripen into a light, buoyant object, which can be blown along for many miles. Some of the so-called "tumble-weeds" of the prairies are of this description, like the tickle-grass, Fig. 183. Other tumble-weeds break off at the root, and the whole plant is

then blown along for great distances, until it is brought to a standstill by a fence or other obstacle. The Russian thistle, of which a small branch is shown in Fig. 184, forms, when growing luxuriantly, roundish bushy masses, as much as three feet high and six feet in diameter. These when dead

FIG. 183. — Partly matured Panicle of Tickle-Grass.[1]

and dry, but loaded with seeds, drift before the wind in such quantities that they often form sloping embankments reaching to the tops of high fences. One such plant has been estimated to carry with it as many as 200,000 seeds.

[1] *Panicum capillare.*

Floating on water is not, in temperate climates, as obvious and important a means of carriage as that by means of the wind, but it is often of great value, and in the case of the cocoanut, with its light fibrous husk and waterproof shell, serves to secure carriage for thousands of miles. It is inter-

FIG. 184. — Portion of a Branch of "Russian Thistle."

esting to notice that the first trees which appear on a coral island, when it emerges above water high enough to support the growth of trees at all, are cocoa palms, sprung from cocoanuts which have floated perhaps half across the South Pacific Ocean.

243. *Destruction of Plants by Unfavorable Climates.* — Land plants, throughout the greater part of the earth's surface, are killed in enormous numbers by excessive heat and drought, by floods or by frost. After a very dry spring or summer the scantiness of the crops, before the era of railroads, which nowadays enable food to be brought in rapidly from other regions, often produced actual famine. Wild plants are not observed so carefully as cultivated ones are, but almost every one has noticed the patches of grass, apparently dead, in pastures and the withered herbaceous plants everywhere through the fields and woods after a long drought.

Floods destroy the plants over large areas, by drowning them, by sweeping them bodily away, or by covering them with sand and gravel.

Frosts kill many annual plants before they have ripened their seeds, and severe and changeable winters sometimes kill perennial plants.

244. *Destruction by Other Plants.* — Overcrowding is one of the commonest ways in which plants get rid of their weaker neighbors. If the market-gardener sows his lettuce or his beets too thickly, few perfect plants will be produced, and the same kind of effect is brought about in nature on an immense scale. Sometimes plants are overshadowed and stunted or killed by the growth all about them of others of the same kind; sometimes it is plants of other kinds that crowd less hardy ones out of existence.

Whole tribes of parasitic plants, some comparatively large, like the dodder and the mistletoe, others microscopic, like blights and mildews, prey during their whole lives upon other plants.

245. *Destruction by Animals.* — All animals are supported directly or indirectly by plants. In some cases the animal secures its food without seriously injuring the plant on which it feeds. Browsing on the lower branches of a tree may do it

little injury, and grazing animals, if not very numerous, may not seriously harm the pasture on which they feed. Fruit-eating animals may even be of much service by dispersing seeds (§ 224). But seed-eating birds and quadrupeds, animals which, like the hog, dig up fleshy roots, root-stocks, tubers or bulbs, and eat them, or animals which, like the sheep, graze so closely as to expose the roots of grasses to be parched by the sun, destroy immense numbers of plants. So too with wood-boring and leaf-eating insects, and snails, which consume great quantities of leaves.

246. *Adaptations to meet Adverse Conditions.* — Since there are so many kinds of difficulties to be met before the seed can grow into a mature plant and produce seed in its turn, and since the earth's surface offers such extreme variations as regards heat, sunlight, rainfall, and quality of soil, it is evident that there is a great opportunity offered for competition among plants. Of several plants of the same kind, growing side by side, where there is room for but one full-grown one, all may be stunted, or one may develop more rapidly than the others, starve them out and shade them to death. Of two plants of different kinds the hardier will crowd out the less hardy, as ragweed, pigweed, and purslane do with ordinary garden crops. Weeds like these are rapid growers, stand drought or shade well, will bear to be trampled on, and, in general, show remarkable toughness of organization.

Plants which can live under conditions which would be fatal to most others will find much less competition than the rank and file of plants are forced to encounter. Lichens, growing on barren rocks, are thus situated, and so are the fresh-water plants, somewhat like pondscum in their structure, which are found growing in hot springs at temperatures of 140°, or in some cases up to 200°.

247. *Examples of Rapid Increase.* — Nothing but the opposition which plants encounter from overcrowding or from

the attacks of their enemies prevents any hardy kind of plant from covering all suitable portions of a whole continent, to the exclusion of most other vegetable life. New Zealand and the pampas of La Plata and Paraguay, in South America, have, during the present century, furnished wonderful examples of the spread of European species of plants over hundreds of thousands of square miles of territory. The new-comers were more vigorous, or in some way better adapted to get on in the world than the native plants which they encountered, and so managed to crowd multitudes of the latter out of existence.

In our own country, a noteworthy case of the kind has occurred so very recently that it is of especial interest to American botanists. The so-called Russian thistle,[1] Fig. 184, which is merely a variety of the saltwort, so common along the Atlantic coast, was first introduced into South Dakota in flaxseed brought from Russia and planted in 1873 or 1874. In twenty years from that time the plant had become one of the most formidable weeds known, over an area of about 25,000 square miles.

HOW PLANTS PROTECT THEMSELVES.

248. *Protection from Weather.* — Several allusions have been made in earlier chapters to the means by which plants defend themselves from excessive cold, moisture, or drought. The varnish and the woolly coating of bud-scales very likely serve the double purpose of preventing sudden changes from heat to cold, and of keeping the tender interior of the bud from becoming watersoaked.

The corky layer of the bark, whether of the stem above-ground, of the underground stem, or of the root, prevents loss of water, as was proved by Exp. 20, § 99.

The waxy coating on the under side of leaves keeps the

[1] *Salsola Kali*, var. *tragus*.

stomata from becoming clogged with water, and the hairy network on the under side of the leaf (into which they often open) may sometimes serve to prevent them from becoming clogged with dust, and certainly often hinders too rapid transpiration.

In regions where there is a long rainless season, many plants produce bulbs in which their nourishment, acquired

FIG. 185. — Arctic Willow. The greater part of a pistillate plant, about natural size.

during the growing season, is buried until the next rainy period comes round.

Desert plants are commonly fleshy and often leafless, in the latter case offering to the dry, scorching air only a small surface of green bark through which transpiration and

respiration take place. Some of the more or less spherical cacti of the dry and treeless plains of the West contain so much stored-up water that men and animals cut or tear them open for the sake of drinking from their pulpy interior.

Arctic plants are sheltered from the savage storms of winter by their habit of clinging to the ground: the Arctic willow, for example, Fig. 185, is only a few inches high.

249. *Defenses against Attacks of Animals.* — Some seeds are bitter or otherwise unpalatable, others poisonous, and still others so hard as to be utterly uneatable. The entire plant is often protected from herbivorous quadrupeds, snails, or destructive insects by the same safeguards which are found in seeds. Walking through a pasture, one may find clumps of buttercups, tansy, ragweed, boneset, dog-fennel, smartweed, or ox-eye daisy[1] which cattle and horses in general will not touch because they are so bitter, pungent, or ill-smelling. Three of the weeds that flaunt themselves most generally in barnyards in the Middle States are dog fennel, Jimpson (Jamestown) weed, and smartweed. The two former are nauseating to the smell and taste; the Jamestown weed is violently poisonous, and the smartweed has a savagely biting flavor.

Fig. 186. — Thorny Branches of Broom.

[1] These species would not all occur in any one pasture, but they are types, and some of them range widely over the country.

Beside the pasture plants above mentioned there grow such others as the bulrushes and hardhack of New England and the ironweed and vervains of the Middle States, which are so harsh and woody that the hungriest browsing animal is rarely, if ever, seen to molest them. Still other plants, like the knotgrass and cinquefoil of our dooryards, are doubly safe, from their growing so close to the ground as to be hard to graze and from their woody and unpalatable nature.

250. *The Weapons of Plants.*[1] — Multitudes of plants which might otherwise have been subject to the attacks of

FIG. 187. — Thorn Leaves of Barberry.

grazing or browsing animals, have acquired what have with reason been called weapons for defense. Shrubs and trees not infrequently produce sharp-pointed branches, like those of the broom, Fig. 186, familiar in our own crab-apple, wild plum, and above all in the honey locust, whose formidable thorns often branch in a very complicated manner.

Thorns which are really modified leaves are very perfectly exemplified in the barberry, Fig. 187. It is much commoner to find the leaf extending its midrib or its veins out into spiny points, as the thistle does, or bearing spines or prickles

[1] See Kerner and Oliver's *Natural History of Plants*, vol. I, p. 430.

on its midrib, as is the case with the nightshade shown in Fig. 88, and with so many roses. Prickles, which are merely hard, sharp-pointed projections from the epidermis, are of too common occurrence to need illustration.

Stipules are not infrequently found occurring as thorns, and in our common locust, Fig. 188, the bud, or the very young shoot, which proceeds from it, is admirably protected by the jutting thorn on either side.

Fig. 188. — Thorn Stipules of Locust.

251. *Pointed, Barbed, and Stinging Hairs.* — Needle-pointed hairs are an efficient defensive weapon of many plants. Sometimes these hairs are roughened, like those of the bugloss, Fig. 189, 6; sometimes they are decidedly barbed. In the nettle, Fig. 189, 3, the hairs are efficient stings, with a brittle tip, which on breaking off, exposes a sharp, jagged tube full of irritating fluid. These tubular hairs, with their poisonous contents, will be found sticking in considerable numbers in the skin of the hand or the face after incautious contact with nettles, and the intense itching which follows is only too familiar to most people.

252. *Cutting Leaves.* — Some grasses and sedges are generally avoided by cattle because of the sharp cutting edges of their leaves, which will readily slit the skin of one's hand if they are drawn rapidly through the fingers. Under the microscope the margins of such leaves are seen to be regularly and thickly set with sharp teeth like those of a saw, Fig. 189, 7, 8.

253. *Weapons of Desert Plants.* — In temperate regions, where vegetation is usually abundant, such moderate means of protection as have just been described are generally suffi-

cient to insure the safety of the plants which have developed them. But in desert or semi-desert regions the extreme scarcity of plant life exposes the few plants that occur there to the attacks of all the herbivorous animals that may encounter them. Accordingly, great numbers of desert

FIG. 189. — Stinging Hairs and Cutting Leaves. (All much magnified.)
3, stinging hairs on leaf of nettle; 6, bristle of the bugloss; 7, barbed margin of a leaf of sedge; 8, barbed margin of a leaf of grass.

plants are characterized by nauseating or poisonous qualities or by the presence of astonishingly developed thorns, while some combine both of these means of defense.

254. *Importance of Adaptiveness in Plants.* — It may be inferred from the preceding sections that a premium is set

on all changes in structure or habits which may enable plants to resist their living enemies or to live amid partially adverse surroundings of soil or climate. It would take a volume to state, even in a very simple way, the conclusions which naturalists have drawn from this fact of a savage competition going on among living things, and it will be enough to say here that *the existing kinds of plants to a great degree owe their structure and habits, their likenesses to each other, and their differences from each other to the operation of the struggle for existence, together with the effort to respond to changes in the conditions by which they are surrounded.* How the struggle for existence has brought about such far-reaching results will be briefly indicated in the next section.

255. *Survival of the Fittest.*—When frost, drought, blights, or other agencies kill most of the plants in any portion of the country, it is often the case that many of the plants which escape do so because they can stand more hardship than the ones which die. In this way delicate individuals are weeded out and those which are more robust survive. But other qualities besides mere toughness often decide which plant or plants of any particular kind shall live and which ones shall die out. In every grove of oaks there are some with sweeter and others with more bitter acorns. One shellbark hickory bears nuts whose shell is easily cracked by hogs, while another protects its seeds by a shell so hard that it is cracked only by a pretty heavy blow. In case of all such differences, there is a strong tendency to have the less eatable fruit or seed preserved and allowed to grow, while the more eatable varieties will be destroyed. Some individuals of the European holly produce bright red berries, while others produce comparatively inconspicuous yellow ones. It has been found that the red berries are much more promptly carried off by birds, and the seeds therefore much more widely distributed, than the yellow ones are. The result of this kind of advantage, in

any of its countless forms, is sometimes called *survival of the fittest,* and sometimes *natural selection.* The latter name means only that the outcome of the process just described, as it goes on in nature, is much the same as that of the gardener's selection, when, by picking out year by year the earliest ripening peas or certain kinds of the oddest-colored chrysanthemums, he obtains permanent new varieties. Natural agencies, acting on an enormous scale through many ages, may well be supposed to have brought about the perpetuation of millions of such variations as are known to be of constant occurrence among plants, wild as well as cultivated.

CHAPTER XXII.

The Classification of Plants.[1]

256. *Natural Groups of Plants.* — One does not need to be a botanist in order to recognize the fact that plants naturally fall into groups which resemble each other pretty closely, that these groups may be combined into larger ones the members of which are somewhat alike, and so on. For example, all the bulb-forming spring buttercups[2] which grow in a particular field may be so much alike in leaf, flower, and fruit that the differences are hardly worth mentioning. The tall summer buttercups[3] resemble each other closely but are decidedly different from the bulbous spring-flowering kind, and yet are enough like the latter to be ranked with them as buttercups. The yellow water-buttercups[4] resemble in their flowers the two kinds above mentioned but differ from them greatly in habit of growth and in foliage, while still another, a very small-flowered kind,[5] might fail to be recognized as a buttercup at all.

The marsh marigold, the hepatica, the rue anemone, and the anemone all have a family resemblance to buttercups,[6] and the various anemones by themselves form another group like that of the buttercups.

257. *Genus and Species.* — Such a group as that of the buttercups is called a *genus* (plural *genera*), while the various kinds of which it is composed are called *species.* Familiar examples of genera are the Violet genus, the Rose genus, the Clover genus, the Golden-rod genus, the Oak genus. The number of species in a genus is very various, — the Kentucky

[1] See Warming and Potter *Systematic Botany* or Kerner and Oliver, vol. II, pp. 616–790. [2] *R. bulbosus.* [3] *R. acris.* [4] *R. multifidus.* [5] *R. abortivus.*

[6] Fresh specimens or herbarium specimens will show this.

Coffee-tree genus contains only one species, while the Golden-rod genus comprises more than forty species in the north-eastern United States alone.

258. *Hybrids.* — If the pollen of a plant of one species is placed on the stigma of a plant of the same genus but a different species no fertilization will usually occur. In a large number of cases, however, the pistil will be fertilized, and the resulting seed will often produce a plant intermediate between the two parent forms. This process is called *hybridization*, and the resulting plant, a hybrid. Many hybrid oaks have been found to occur in a state of nature, and hybrid forms of grapes, orchids, and other cultivated plants are produced by horticulturists at will.

259. *Varieties.* — Oftentimes it is desirable to describe and give names to sub-divisions of species. All the cultivated kinds of apple are reckoned as belonging to one species, but it is convenient to designate such varieties as the Baldwin, the Bellflower, the Rambo, the Gravenstein, the Northern Spy, and so on. Very commonly varieties do not, as horticulturists say, "come true," that is to say, the seeds of any particular variety of apple not only are not sure to produce that variety, but they are nearly sure to produce a great number of widely different sorts. Varieties which will reproduce themselves from the seed, such as pop-corn, sweet corn, flint-corn, and so on, are called *races*.

Only long and careful study of plants themselves and of the principles of classification will enable any one to decide on the limits of the variety, species, or genus, that is, to determine what plants shall be included in a given group and what ones shall be classed elsewhere.

260. *Order or Family.* — Genera which resemble each other somewhat closely, like those discussed in § 256, are classed together in one order or family. The particular genera above mentioned, together with a large number of

others, combine to make up the Crowfoot family. In determining the classification of plants most points of structure are important, but the characteristics of the flower and fruit outrank others because they are more constant, since they vary less rapidly than the characteristics of roots, stems, and leaves do under changed conditions of soil, climate, or other surrounding circumstances. Mere size or habit of growth has nothing to do with the matter, so that the botanist finds no difficulty in recognizing the strawberry plant and the apple tree as members of the same family.

This family affords excellent illustrations of the meaning of the terms genus, species, and so on. Put in a tabular form, some of the sub-divisions of the Rose family are as follows:

The Rose family includes (among many others):

- Plum genus
  - Peach species (many varieties).
  - Garden plum species (many varieties).
  - Wild black cherry species.
  - Garden red cherry species (many varieties).
- Rose genus
  - Dwarf wild rose species.
  - Sweet-brier species.
  - India rose species
    - Tea variety.
    - Pompon variety, etc.
  - Damask rose species.
- Pear genus
  - Pear species
    - Seckel variety.
    - Bartlett variety.
    - Sheldon variety, etc.
  - Apple species
    - Baldwin variety.
    - Greening variety.
    - Bellflower variety.
    - Northern Spy variety, etc.

261. *Grouping of Families.* — Families are assembled into *classes*, and these again into larger groups. The details of the entire plan of classification are too complicated for any but professional botanists to master, but an outline of the scheme may be given in small space.

The entire vegetable kingdom is divided into two great series, the first consisting of *cryptogamous* or flowerless plants, the second of *phanerogamous* or flowering plants. Here the relations of the various subdivisions may best be shown by a table.[1]

262. *Table of the Classification of the Vegetable Kingdom.*

SERIES I. CRYPTOGAMOUS OR FLOWERLESS PLANTS	GROUP I. THALLOPHYTES, or *leafless cellular cryptogams*	Consists of about ten classes, among the most familiar members of which are the seaweeds, yeasts, mildews, moulds, toadstools, lichens, etc.
	GROUP II. BRYOPHYTES, or *moss-like plants*	Consists of two classes, the liverworts and the mosses.
	GROUP III. PTERIDOPHYTES, or *fern-like plants.*	Consists of three classes, the ferns, the horsetails, and the lycopodiums.
SERIES II. PHANEROGAMOUS OR FLOWERING PLANTS[2]	CLASS I. GYMNOSPERMS, or conebearers, such as pines, spruces, cedars, and many other evergreen trees.	
	CLASS II. ANGIOSPERMS, or *ordinary flowering plants.*	SUB-CLASS I. MONOCOTYLEDONOUS PLANTS. SUB-CLASS II. DICOTYLEDONOUS PLANTS.

[1] This is, of course, only for consultation, and not to be committed to memory by the student.

[2] The teacher will notice that this table is carried out a little more in detail than that of Series I, since its subject-matter is more familiar and the number of classes of phanerogams is so much smaller than that of cryptogams.

263. *Plants form an Ascending Series.* — All modern systems of classification group plants in such a way as to show a succession of steps, often irregular and broken, seldom leading straight upward, from very simple forms to highly complex ones. The humblest thallophytes are merely single cells, usually of microscopic size. Class after class shows an increase in complexity of structure and of function until the most perfectly organized plants are met with among the dicotyledonous angiosperms. During the latter half of the present century it first became evident to botanists that among plants *deep-seated resemblances imply actual relationship, the plants which resemble each other most are most closely akin by descent, and (if it were not for the fact that countless forms of plant life have wholly disappeared) the whole vegetable kingdom might have the relationships of its members worked out by a sufficiently careful study of the life histories of individual plants and the likenesses and differences of the several groups which make up the system of classification.*[1]

264. *Order of Appearance of Types of Plant Life on the Earth.* — Fossil remains of plants are found preserved in the rocks in so many places that much is known about the early history of plant life. Thallophytes of some kind were undoubtedly the first plants, and more highly organized groups appeared gradually afterward. It is nearly as certain that the more complex and highly specialized forms descended by gradual modifications and improvements from the simpler ones as it is that elm trees a hundred feet in height, with all their complicated structures of root, stem, leaf, and flower, grow from seeds not nearly as large as one's finger-nail. But

[1] See Warming's *Systematic Botany*, Preface and throughout the work. In the little flora which accompanies Part II of the present book, the families are arranged not in the order in which they occur in Gray's *Manual*, but in one which according to the best recent German authorities more nearly represents their relationships.

the study of fossil plants and that of the way in which one group of plants has descended from another are topics too difficult to receive more than a simple mention in an ordinary school botany.

CHAPTER XXIII.

Some Types of Flowerless Plants.[1]

265. *Numerous Classes of Cryptogamous Plants.* — While there are only two classes of flowering plants (§ 256), and only the latter of these need occupy much of the attention of a beginner in botany, there are some fifteen classes of flowerless plants, so that an elementary book on botany can only make the student acquainted with a few specimen groups chosen from among these.

THE STUDY OF PROTOCOCCUS.[2]

266. *Occurrence.* — Protococcus may be found in the water of stagnant pools, particularly of those which contain the drainage of barn-yards or of manure-heaps. It occurs also in the mud at the bottom of eaves-troughs, in barrels containing rain-water, or in water standing in cavities in logs or the stumps of trees. Water containing Protococcus in abundance is greenish (or sometimes reddish) throughout, while examination with the naked eye hardly shows the separate particles to which the color is due. Portions of the mud on which the plant occurs should be carefully scraped off and kept damp for examination, or the water in

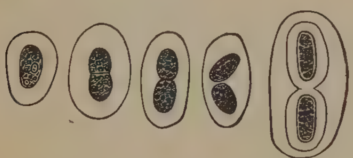
[1] The author has introduced the study of a few cryptogamous forms thus late in the present book more out of deference to general usage than because he thinks it to be the best possible order of treatment. He has found it desirable to exhibit (under the microscope) and discuss slides of *Protococcus*, *Pleurococcus*, *Palmella*, and so on, as soon as the pupil is shown the cellular structure of seeds. This emphasizes and makes clear at the outset something of the nature of the vegetable cell. *Protococcus* and *Spirogyra* may be examined for chlorophyll, and their liberation of oxygen in sunlight noted while the work of the leaf is under consideration. Finally the structure and the reproduction of all the cryptogamous forms which are to be considered at all may be investigated and discussed just before the study of the flower is begun.

[2] See Huxley and Martin's *Biology* (extended by Howes and Scott) under Protococcus.

which Protococcus is growing should be put in a shallow dish, loosely covered with a pane of glass, to prevent drying up, and set in a sunny place.[1]

267. *Microscopical Examination of Protococcus.*[2] — Place a drop of water containing Protococcus on a slide, lay on it a cover-glass, and examine with a power of 200 or more diameters. Sketch with the *camera lucida* several divisions of the stage micrometer alongside of one of the largest cells, some of intermediate size, and one of the smallest.[3]

Note the clearly defined cell wall, of cellulose, enclosing the protoplasmic contents, usually green throughout, sometimes red throughout, sometimes of both colors. Do any cells show a nucleus like that in Fig. 102 *e*, *f*, *g*, *k*, *l*?



A B C D E

FIG. 190. — A Unicellular Plant (*Palmoglæa*). (Greatly magnified.)

A, a single cell in its ordinary condition, consisting of a mass of protoplasm colored green by chlorophyll and surrounded by a transparent gelatinous envelope; *B*, the cell-contents elongating preparatory to multiplying by fission into two portions; *C*, the process carried a step farther; *D*, the two cells quite distinct, but surrounded by a common gelatinous envelope; *E*, each of the new cells much enlarged and forming a gelatinous envelope of its own.

Test the cells with iodine for starch.

Note that the cell-contents in many individuals has divided into two parts, which become separated from each other by a cellulose partition. The mode of division is not unlike that shown in Fig. 190, but the cells in that figure have not the distinct cell wall that Protococcus has, while they are covered with a layer of gelatinous material not found in Protococcus. After the division of a Protococcus cell into two portions, each may at once constitute a new cell, with a complete sac of cellulose surrounding it, or each of the halves formed by the first sub-division may break up into halves again before the cell wall is formed around the new portions.

[1] If it is found impracticable to collect *Protococcus* for examination, the green, powdery *Pleurococcus* found everywhere on the shady sides of trees or unpainted fences will answer very well to show unicellular plants containing chlorophyll, and to illustrate multiplication by cell-division.

[2] Slides permanently mounted and purchasable of the dealers (see Appendix C) will answer for most of the microscopical examinations almost as well as the living cells.

[3] See Clark's *Practical Methods in Microscopy*, pp. 31–35.

268. *Motile Form of Protococcus.* — Occasionally the Protococcus cell may be found in an actively swimming condition, known as its *motile form.* The larger motile cells are either naked or are covered with a transparent cell wall, which the colored cell-contents does not entirely fill. The latter condition is represented by Fig. 191, II. These large motile cells may multiply by a process known as *fission* into twos or fours, or the whole cell-contents may break up into as many as 32 portions, each of which then sets out in an independent existence as a freely swimming spore (*zoöspore*).

The change from the still to the motile form appears to be favored by heat, sunlight, and abundance of air-supply (as by shallowness of the water in which the plants are growing); the reverse change is brought about by conditions just the opposite of those above mentioned.

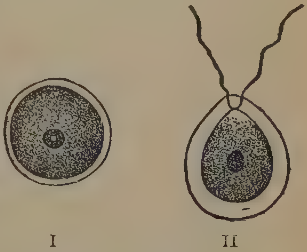


FIG. 191. — Two Cells of Protococcus. (Greatly magnified.)

I, a spherical cell of the still form; II, a motile cell with its protoplasm enclosed in a loose cell wall and provided with two cilia (§ 161).

269. *Nutrition of Protococcus.* — Protococcus can flourish only in the sunlight, but with a sufficient supply of light it can absorb and fix carbonic acid gas (giving off at the same time bubbles of oxygen) and can assimilate mineral substances. It is a capital example of an individual cell capable of independent existence.

THE STUDY OF SPIROGYRA.[1]

270. *Occurrence.* — *Spirogyra*, one of the plants commonly known as pondscum, or "frog-spit," occurs widely distributed throughout the country in ponds, springs, and clear streams. It is of a green or yellowish-green color, and in sunny weather usually floats on or near the surface of the water buoyed up by the numerous oxygen bubbles which it sets

[1] If *Spirogyra* is not easily found, the teacher may advantageously use *Zygnema* or *Mesocarpus.* He should become familiar with the appearance of some of the fresh-water algæ by microscopical studies of them and by reference to the figures in such works as Wood's *Fresh-Water Algæ.* There are many excellent small cuts of common forms in Campbell's *Elements of Structural and Systematic Botany*, published by Ginn & Co. The teacher may consult this latter book to great advantage throughout his studies on cryptogamous plants.

free. It may be found flourishing in unfrozen springs, even in midwinter.

271. *Examination with the Magnifying Glass.*[1] — Float a little of the material in a white plate, using just water enough to cover the bottom of the latter. Study with the magnifying glass and note the green color of the threads and their great length as compared with their thickness. Are all the filaments about equal to each other in diameter?

Handle a mass of the material and describe how it feels between the fingers.

FIG. 192. — Cell from a Thread of Pondscum (*Spirogyra*). (Magnified about 90 diameters.)

k, nucleus; *ch*, spiral band containing chlorophyll; *p*, *pyrenoids*, little masses of proteid material with starch-grains.

272. *Examination with the Microscope.*—Mount in water under a large cover-glass and examine first with a power of about 100 diameters, then with a power of 200 diameters or more. Note the structure of the filaments, each made up of a row of cells placed end to end.

Move the slide so as to trace the whole length of several filaments, and, if the unbroken end of one can be found, study and sketch it.

Study with the higher power a single cell of one of the larger filaments and make out the details of structure shown in Fig. 192. Try to ascertain, by focusing, the exact shape of the cell. Count the bands of chlorophyll. The number of bands is an important character in distinguishing one species from another.

Run in five-per-cent salt solution at one edge of the cover-glass (withdrawing water from the other edge with a bit of blotting-paper). If any change in the appearance of the cell becomes evident, make a sketch to show it. What has happened to the cell-contents? Explain, by reference to what you know of osmose, the cause of the change.

On a freshly mounted slide run in iodine solution, a little at a time, and note its action on the nucleus. Is any starch shown to be present? If so, just how is it distributed through the cell?

273. *Reproduction of Spirogyra.* — The reproductive process in *Spirogyra* is of two kinds, the simplest being a process of fission, not unlike that with which the student has become familiar in *Protococcus*. The nucleus undergoes a very complicated series of transformations,

[1] Consult Huxley's *Biology* and Spalding's *Introduction to Botany*.

which result in the division of the protoplasmic contents of a cell into two independent portions, each of which is at length surrounded by a complete cell wall of its own. In Fig. 193 the division of the protoplasm and formation of a partition of cellulose in a kind of pondscum are shown, but the nucleus and its changes are not represented.

Another kind of reproduction, namely by *conjugation*, is found in *Spirogyra*. This process in its simplest form is found in such unicellular plants as the *desmids*, Fig. 194. Two cells (apparently precisely alike) come in contact, undergo a thinning-down or absorptive process in the cell walls at the point of contact, and finally blend their protoplasmic cell-contents, as shown in the figure, to form a mass known as a *spore*, or more accurately a *zygospore*, from which a new individual soon

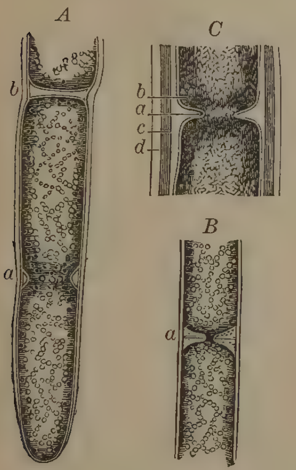


FIG. 193. — Process of Cell-Multiplication in a Species of Pondscum. (Considerably magnified.)

A, portion of a filament partly separated at *a* and completely so at *b*; *B*, separation nearly completed, a new partition of cellulose formed at *a*; *C*, another portion, more magnified, showing mucous covering *d*, general cell wall *c*, and a delicate membrane *a*, which covers the cell-contents *b*.

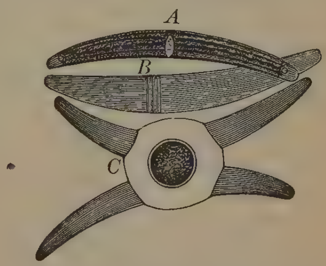


FIG. 194. — Unicellular Fresh-Water Plants (*desmids*), forming Spores by Conjugation. (Much magnified.)

A, a single plant in its ordinary condition; *B*, empty cell wall of another individual; *C*, conjugation of two individuals to form a spore by union of their cell-contents.

develops. In *Spirogyra* each cell of the filament appears to be an individual and can conjugate like the one-celled *desmids*. It is not easy to watch the process, since the growth of the filaments goes on mainly by day, in sunlight, and the spore-formation takes place at night, when growth is less rapid. It is possible, however, to retard the occurrence of

conjugation by leaving the Spirogyra filaments in very cold water over night, and in this way the successive steps of the conjugating process may be studied by daylight. In such ways the series of phenomena shown in Fig. 195 has been clearly made out. If the student cannot follow these operations under the microscope, he may at least by looking over the yellower portions of a mass of Spirogyra find threads containing fully formed zygospores, like those shown in *B*, Fig. 195.

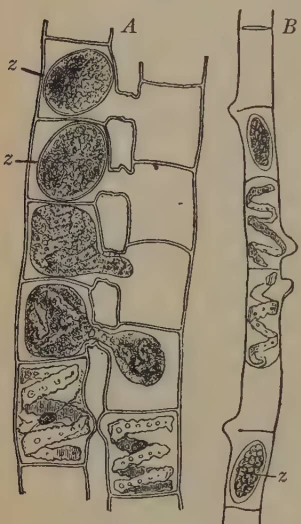


FIG. 195. — Formation of Spores by Conjugation in Spirogyra.

A, two filaments of Spirogyra side by side, with the contents of adjacent cells uniting to form spores *z*. At the bottom of the figure the process is shown as beginning, at the top as completed, and the cells of one filament emptied; *B*, a single filament of another kind of Spirogyra, containing two spores, one lettered *z*. (*A* magnified 240 diameters, *B* 150 diameters.)

ALGÆ.

274. *Characteristics of Algæ.* — The *Protococcus* and the *Spirogyra* are two common fresh-water examples of the kind of plants classed under the general name of *Algæ*, a group of which the largest and most interesting examples are to be found among the seaweeds. Algæ are all aquatic, or at least live usually in damp places; they contain chlorophyll, and are therefore capable of absorbing carbonic acid gas and fixing carbon; few algæ are parasitic or saprophytic. In fact, the main distinction between this group and the *fungi* lies in the self-supporting character of the former plants and the parasitic or saprophytic (§ 151) character of the latter. For this reason the two groups, based on the characteristic behavior or mode of life of their members, rather than on the real relationships of the

latter, are not certain hereafter to be recognized in any strictly scientific classification of cryptogamous plants.

Algæ vary in size from spheres $\frac{1}{10,000}$ inch in diameter to great cable-like masses many hundreds of feet in length. Some species are found in salt, some in brackish, some in fresh water. There are species which occur growing on snow and melting ice, while others form the characteristic vegetation of hot springs, in which they sometimes endure a temperature nearly equal to that of boiling water.

275. *Reproduction in Algæ.* — The reproductive processes in algæ are of several types, which are described in special treatises but cannot be explained in detail in a botany for beginners. Besides the mode by formation of *zoöspores*, as in the *Protococcus*, and that by the formation of *zygospores*, as in the desmids and in *Spirogyra*, there is a very interesting method which may be briefly outlined here, because it represents an important principle in many kinds of reproduction, *the union of fertilizing cells with much larger egg-cells.* This kind of union is well illustrated by one of the very commonest of seaweeds, the common bladder-wrack or rockweed, Fig. 196, which grows on rocks between high and low water mark. It has many flat, leathery branches, which are buoyed up in the water by the air-bladders, *b*. The spores are produced by means of a rather complicated set of organs con-

FIG. 196. — Common Bladder-Wrack or Rockweed, *Fucus vesiculosus*. (Reduced to about ⅓ the natural size.) *b*, air-bladders; *f*, organs for production of spores.

tained in the expanded portions, *f*. In these expansions there are produced somewhat spherical bodies, *A*, Fig. 197, which may be called egg-cells (*oöspheres*), and ciliated fertilizing cells, or *antherozoids*, *G*. After the bursting of the thin membrane, shown at *A*, by which the egg-spheres are confined, they become covered with multitudes of the fertilizing cells, as seen at *F* and *H*, and are often whirled about by the motion of the cilia of these cells. At length, the sub-

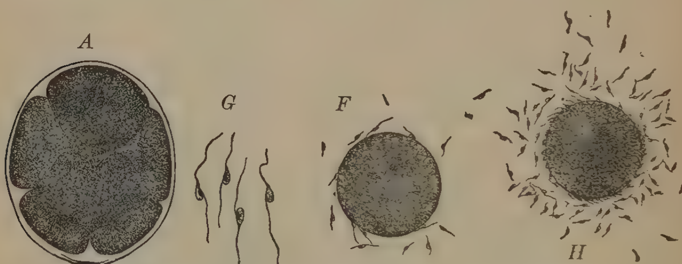


FIG. 197. — Production of Spores of Rockweed. (Much magnified.)[1]
A, a bundle of egg-spheres, or oöspheres (from interior of *f*, Fig. 196); *G*, ciliated fertilizing cells, or antherozoids (from interior of *f*, Fig. 196); *F*, *H*, egg-spheres changing to spores by union of fertilizing cells with their contents. (*G* is magnified more than twice as much as the other parts of the figure.)

stance of one of the ciliated cells becomes mingled with that of the naked protoplasmic egg-sphere, and the latter soon proceeds to develop a cell wall and begins at once to grow into a new plant of rockweed.

THE STUDY OF YEAST.

276. *Growth of Yeast in Dilute Syrup.* — Mix about an eighth of a cake of compressed yeast with about a teaspoonful of water and stir until a smooth thin mixture is formed. Add this to about half a pint of water in which a tablespoonful of molasses has been dissolved. Place this mix-

[1] *A* and *F* of this figure represent the spore-producing apparatus from *Fucus platycarpus*. Fig. 196 is *Fucus vesiculosus*. The principle of spore-formation is very similar in the two species.

ture in a wide-mouthed bottle which holds one or one and a half pints, stopper *very loosely*[1] and set aside for from 12 to 24 hours in a place in which the temperature will be from 70 to 90 degrees. Watch the liquid meantime and note:

(*a*) The rise of bubbles of gas in the liquid.

(*b*) The increasing muddiness of the liquid, a considerable sediment usually collecting at the end of the time mentioned.

(*c*) The effect of cooling off the contents of the bottle by immersing it in broken ice if convenient, or if this is not practicable by standing it for half an hour in a pail of the coldest water obtainable, or leaving it for an hour in a refrigerator, afterwards warming the liquid again.

(*d*) The effect of shutting out light from the contents of the bottle by covering it with a tight box or large tin can.

(*e*) The result of filling a test-tube or a very small bottle with some of the syrup-and-yeast mixture, from which gas-bubbles are freely rising, and immersing the small bottle up to the top of the neck for fifteen minutes in boiling water. Allow this bottle to stand in a warm place for some hours after the exposure to hot water.

(*f*) The behavior of a lighted match lowered into the air-space above the liquid in the large bottle after the latter has been standing undisturbed in a warm place for an hour or more.

(*g*) The smell of the liquid and its taste.

277. *Microscopical Examination of the Sediment*[2] — Using a very slender glass tube as a pipette, take up a drop or two of the liquid and the upper layer of the sediment and place on a glass slide, cover with a very thin cover-glass and examine with the highest power that the microscope affords.

Note:

(*a*) The general shape of the cells.

(*b*) Their granular contents.

(*c*) The clear spot or vacuole seen in many of the cells.

Sketch some of the groups and compare the sketches with Fig. 198.

Run in a little iodine solution under one edge of the cover-glass, at the same time touching a bit of blotting-paper to the opposite edge, and notice the color of the stained cells. Do they contain starch?

Place some vigorously growing yeast on a slide under a cover-glass and run in a little red ink. Note the proportion of cells which stain at first and the time required for others to stain. Repeat with yeast which has

[1] If the cork is crowded into the neck with any considerable force, pressure of gas and an explosion may result.

[2] See Huxley and Martin, under *Torula*.

been placed in a slender test-tube and held for two or three minutes in a cup of boiling water.

With a very small cover-glass, not more than $\frac{3}{8}$ inch in diameter, it may be found possible by laying a few bits of blotting-paper or card-board on the cover-glass and pressing it against the slide to burst some of the stained cells and thus show their thin, colorless *cell walls* and their semi-fluid contents, *protoplasm*, nearly colorless in its natural condition but now stained by the iodine.

278. ***Experiment 33.*** *Can Yeast grow in Pure Water or in Pure Syrup?* — Put a bit of compressed yeast of about the size of a grain of wheat in about four fluid-ounces of distilled water, and another bit of about the same size in four fluid-ounces of 10-per-cent solution of rock candy in distilled water; place both preparations in a warm place, allow to remain for 24 hours and examine for evidence of the growth of the yeast added to each.

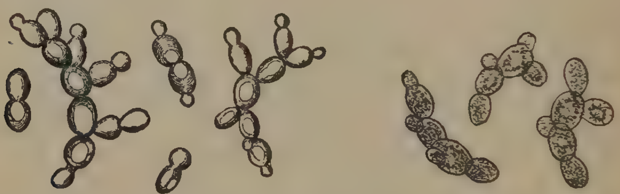


FIG. 198. — Two Species of Yeast, increasing by Budding. (Greatly magnified.) I, a species with the buds very numerous and well defined. II, the common species.

279. *Size, Form, and Structure of the Yeast Cell.* — The student has discovered by his own observations with the microscope that the yeast cell is a very minute object, — much smaller than most of the vegetable cells which he has hitherto examined. The average diameter of a yeast cell is about $\frac{1}{3000}$ of an inch, but they vary greatly both ways from the average size. (Measure an average cell in Fig. 198, II, and calculate about how many diameters magnifying power were used for that figure.)

The general form of most of the cells of ordinary yeast is somewhat egg-shaped. The structure is extremely simple, consisting of a thin cell wall, which is wholly destitute of markings, and a more or less granular semi-fluid protoplasm, sometimes containing a portion of clearer liquid, the *vacuole*, well shown in the larger cells of Fig. 198, I.

280. *Substances which compose the Yeast Cell.* — The cell wall is composed mostly of *cellulose*, the protoplasm consists largely of water together with considerable portions of a proteid substance,[1] some fat, and very minute portions of *sulphur*, *phosphorus*, *potash*, *magnesia*, and *lime*. It is destitute of chlorophyll, as would be inferred from its lack of green color, and contains no starch.

281. *Food of the Yeast Cell, Fermentation.* — Yeast cannot grow much in pure water nor in pure solution of sugar. The diluted molasses in which it was grown in Exp. 33 contained all the mineral substances mentioned in § 280, together with sugar, proteid materials, and water. The addition of a little nitrate of ammonium would probably have aided the growth of the yeast in this experiment, by supplying more abundantly the elements out of which the yeast constructs its proteid cell-contents. A great deal of sugar disappears during the growth of the yeast.[2] Most of the sugar destroyed is changed into carbonic acid gas (which the student saw rising through the liquid in bubbles), and alcohol, which can be separated from the liquid by simple means. The process of breaking up weak syrup into carbonic acid and alcohol by aid of yeast is called *fermentation*, it is of great practical importance in bread-making and in the manufacture of alcohol. Since grape juice, sweet cider, molasses-and-water, and similar liquids when merely exposed to the air soon begin to ferment, and are then found to contain growing yeast, it is concluded that dried yeast cells, in the form of dust, must be everywhere present in ordinary air.

282. *Yeast a Plant; a Saprophyte.* — The yeast cell is known to be a plant, and not an animal, from the fact of its producing a coating of cellulose around its protoplasmic contents and from the fact that it can produce proteids out of substances from which animals could not produce them.[3]

On the other hand, yeast cannot live wholly on carbonic acid gas, nitrates,

[1] It may be found troublesome to apply tests to the yeast cell on the slide, under the cover-glass. Testing a yeast cake is not of much value, unless it may be assumed that compressed yeast contains little foreign matter and consists mostly of yeast cells. Still the test is worth making. Millon's reagent does not work well, but the red or maroon color which constitutes a good test for proteids is readily obtained by mixing a teaspoonful of granulated sugar with enough strong sulphuric acid to barely moisten the sugar throughout, and then, as quickly as possible, mixing a bit of yeast cake with the acid and sugar. A comparative experiment may be made at the same time with some other familiar proteid substance, *e.g.*, wheat germ meal.

[2] The sugar contained in molasses is partly cane sugar and partly grape sugar. Only the latter is detected by the addition of Fehling's solution. Both kinds are destroyed during the process of fermentation.

[3] For example, tartrate of ammonia.

water, and other mineral substances, as ordinary green plants can. It gives off no oxygen, but only carbonic acid gas, and is therefore to be classed with the *saprophytes*, like the Indian pipe among flowering plants, § 151.

283. *Multiplication of Yeast.* — While yeast cells are under favorable conditions for growth, they multiply with very great rapidity. Little protrusions are formed at some portion of the cell wall, as the thumb of a mitten might be formed by a gradual outgrowth from the main portion. Soon a partition of cellulose is constructed, which shuts off the newly formed outgrowth, making it into a separate cell, and this in turn may give rise to others, while meantime the original cell may have thrown out other offshoots. The whole process is called *reproduction by budding.* It is often possible to trace at a glance the history of a group of cells, like those of the right-hand cluster in Fig. 198, II, the oldest and largest cell being somewhere near the middle of the group and the youngest and smallest members being situated around the outside. Less frequently the mode of reproduction is by means of *spores*, new cells (usually four in number), formed inside one of the older cells. At length the old cell wall bursts and the spores are set free, to begin an independent existence of their own.

In examining the yeast cell, the student has been making the acquaintance of plant life reduced almost to its lowest terms. The very simplest plants consist, like the slime-moulds, of a speck of jelly-like protoplasm. Yeast is more complex, from the fact that its protoplasm is surrounded by an envelope of cellulose, the cell wall.

THE STUDY OF BLACK MOULD.[1]

284. *Occurrence.* — This mould may be found in abundance on decaying fruits, such as tomatoes, apples, peaches, grapes, and cherries, or on decaying sweet potatoes or squashes. For class study it may most conveniently be obtained by putting pieces of wet bread on plates for a few days under bell jars and leaving in a warm place until patches of the mould begin to appear.[2]

[1] *Rhizopus nigricans.* If any difficulty is experienced in procuring material for study, the common sage-green mould, *Penicillium glaucum*, can always be procured and propagated as described in Huxley and Martin's *Biology*.

[2] It will always be found much easier to obtain a good crop of the desired mould by sowing its spores upon the wet bread that is used. Spores may be kept indefinitely, in a dry condition, for this purpose. Exposing the bread to a confined portion of the atmosphere of any place, *e.g.*, a cellar, where the desired mould has previously flourished will insure a prompt growth of the mould anew.

285. *Examination with the Magnifying Glass.* — Study some of the larger and more mature patches and some of the smaller ones. Note :

(*a*) The slender, thread-like network with which the surface of the bread is covered. The threads are known as *hyphæ*, the entire network is called the *mycelium*.

(*b*) The delicate threads which rise at intervals from the mycelium and are terminated by small globular objects. These little spheres are spore-cases. Compare some of the spore-cases with each other and notice what change of color marks their coming to maturity.

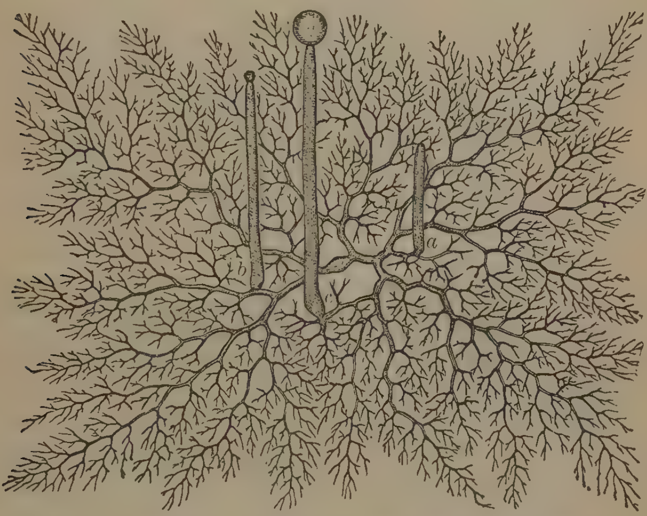


FIG. 199. — Unicellular Mycelium of a Mould (*Mucor Mucedo*), sprung from a Single Spore.

a, *b*, and *c*, branches for the production of spore-cases showing various stages of maturity. (Considerably magnified.)

286. *Examination with the Microscope.* — Sketch a portion of the untouched surface of the mould as seen (opaque) with a two-inch objective, then compare with Fig. 199.

Wet a bit of the mould, first with alcohol, then with water. Examine in water with the half-inch objective and sketch a little of the mycelium, some of the spore-cases, and the thread-like stalks on which they are

borne. Are these stalks and the mycelium filaments solid or tubular? Are they one-celled or several-celled?

Mount some of the mature spore-cases in water, examine them with the highest obtainable power, and sketch the escaping spores.

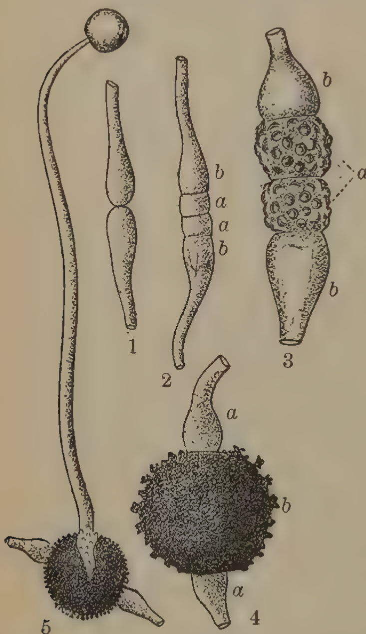


FIG. 200. — Formation of Zygospores in a Mould (*Mucor Mucedo*).

1, threads in contact previous to conjugation; 2, cutting off of the conjugating cells, *a*, from the threads, *b*; 3, a later stage of the process; 4, ripe zygospore; 5, germination of a zygospore and formation of a spore-case. (1-4 magnified 225 diameters, 5 magnified about 60 diameters.)

Sow some of these spores[1] on the surface of "hay-tea," made by boiling a handful of hay in just water enough to cover it and then straining through cloth or filtering through a paper filter. After from three to six hours, examine a drop from the surface of the liquid with a medium power of the microscope (half-inch objective) to see how the development of hyphæ from the spores begins. Sketch.

After about 24 hours examine another portion of the mould from the surface of the liquid and study the more fully developed mycelium. Sketch.

287. *Zygospores.* — Besides the spores just studied, *zygospores* are formed by conjugation of the hyphæ of the black moulds. It is not very easy to find these in process of formation, but the student may be able to gather from Fig. 200 the nature of the process by which they are formed: a process which cannot fail to remind him of the conjugation of pondscum.

FUNGI.

288. *Characteristics of Fungi.* — The yeasts and the moulds are humble representatives of an immense multitude of para-

[1] The spores of *Penicillium* will do as well.

sitic or saprophytic plants which were formerly all grouped as *fungi*, but which now are often divided among many classes.[1] Chlorophyll is absent from fungi, and they are destitute of starch, but produce a kind of cellulose which appears to differ chemically from that of other plants. Unable to build up their tissues from carbonic acid gas, water, and other mineral matters, they are to be classed, with animals, as consumers rather than as producers, acting on the whole to diminish rather than to increase the total amount of organic material on the earth.

289. *Occurrence and Mode of Life of Fungi.* — Among the most important cryptogamous plants are those which, like the bacillus of consumption, of diphtheria, of typhoid fever, or of cholera, produce disease in man or in the lower animals. The sub-class which includes these plants is known by the name *Bacteria.* Some of the most notable characteristics of this group are their extreme minuteness and their extraordinary power of multiplication. Many bacteria are on the whole highly useful to man, as is the case with those which produce decay in the tissues of dead plants or animals, since these substances would, if it were not for the destructive action of the bacteria of putrefaction and fermentation, remain indefinitely after death to cumber the earth and lock up proteid and other food needed by new organisms.

The "rust" of wheat and the "smut" of corn are well-known fungi parasitic on other plants, and the number of such species of fungi already known is not less than 42,000. Fig. 201 shows clearly how a parasitic fungus grows from a spore which has found lodgment in the tissues of a leaf and pushes out stalks through the stomata.

The largest fungi are those of the group to which the edible mushrooms, the toadstools, puffballs, and so on, belong.

[1] See Strasburger, Noll, Schenck, and Schimper's *Lehrbuch*, pp. 262, 263; also Warming's *Systematic Botany* (translated by Potter), p. 1.

The mycelium of these is generally concealed in the substance of the earth, decaying wood, or other material on which the fungus grows, and the conspicuous portion of the plant is that on which the spores are borne.

Lichens, familiar objects encrusting rocks or hanging in

FIG. 201. — Spore-Formation in Potato Blight (*Phytophthora infestans*).
A, an unbranched stalk, proceeding from the mycelium *m* in the interior of the potato leaf, passing out of the epidermis *e* through the stoma *sp*, and bearing a single spore-case; *B*, an older group of stalks, showing spore-cases in various stages. (Both greatly magnified, *A* more highly than *B*.)

beard-like tufts from the bark of trees, which were once regarded as constituting a separate division of the vegetable kingdom, are now known to be curious examples of a kind of

partnership which occurs both among plants and among animals. The so-called lichen is really a complex colony composed of a multitude of minute fungi living in close connection with certain thread-like algæ. The partnership between the two kinds of plants is not an especially one-sided affair; though the algæ are the principal breadwinners of the firm, their association with the fungi enables them to live in situations and under conditions that would be fatal to the algæ alone.

290. *Reproduction in Fungi.* — The reproductive processes in fungi are so various in their character, and involve so much microscopical study, if they are to be clearly understood, that it would require many chapters to describe them. The examples already considered in the cases of yeast and the moulds must be allowed to stand as representatives of the great number of interesting types that offer themselves to the student of this department of cryptogamic botany.

THE STUDY OF PIGEON-WHEAT MOSS.[1]

291. *Occurrence.* — This moss, Fig. 202, is widely distributed over the surface of the earth, and some of its species are among the best-known mosses of the northern United States. Here it grows commonly in dry pastures or on hillsides, not usually in densely shaded situations.

292. *Form, Size, and General Characters.* — Study several specimens which have been pulled up by the roots.[2] Note the size, general form, color, and texture of all the parts of the plants examined. Some of them probably bear *urns* or *spore-capsules* like those shown in Fig. 202, while others are without them. Sketch one plant of each kind, about natural size.

What difference is noticeable between the appearance of the leaves in those plants which have spore-cases and those which have none? Why is this?

[1] *Polytrichum commune.* This is selected as one of the largest and commonest of mosses. If any other genus is more readily obtainable, the teacher may as well use it. For an excellent account of the structure and physiology of mosses, consult Bennett and Murray's *Cryptogamic Botany.* For the determination of species, see Lesquereux and James' *Mosses of North America.*

[2] Fresh specimens are best, but dried ones will do nearly as well.

FIG. 202. — A Plant of Pigeon-Wheat Moss (*Polytrichum commune*). *rh*, root-like portion; *s*, bristle-like stalk of urn, or spore-case; *c*, hoodlike cover of urn; *ap*, knob at base of urn; *d*, cover of urn. (Natural size.)

In some specimens the stem may be found, at a height of an inch or more above the roots, to bear a conical, basket-shaped enlargement, out of the centre of which a younger portion of the stem seems to proceed, and this younger portion may in turn end in a similar enlargement, from which a still younger part proceeds.

Note the difference in general appearance between the leaves of those plants which have just been removed from the moist collecting-box and those which have been lying for half an hour on the table. Study the leaves in both cases with the magnifying glass in order to find out what has happened to them. Of what use to the plant is this change? Put some of the partially dried leaves in water, in a cell on a microscope slide, cover, place under the lowest power of the microscope, and examine at intervals of ten or fifteen minutes. Finally sketch a single leaf.

293. *Minute Structure of the Leaf and Stem.* —The cellular structure of the pigeon-wheat moss is not nearly as simple and convenient for microscopical study as is that of the smaller mosses, many of which have leaves composed, over a large part of their surfaces, of but a single layer of cells, as shown in Fig. 205. If any detailed study of the structure of a moss is to be made it will, therefore, be better for the student to provide himself with specimens of almost any of the smaller genera,[1] and work out what he can in regard to their minute anatomy.

294. *Spore-Capsules.* — That part of the reproductive apparatus of a common moss which is most apparent at a glance is the *urn* or *spore-capsule*, Fig. 202. This is covered until it reaches maturity with a hood which is easily detached. Remove the hood from one of the

[1] As *Mnium* or *Bryum*.

urns, examine with the magnifying glass, and sketch it. Note the character of the material of which its outer layer is composed.

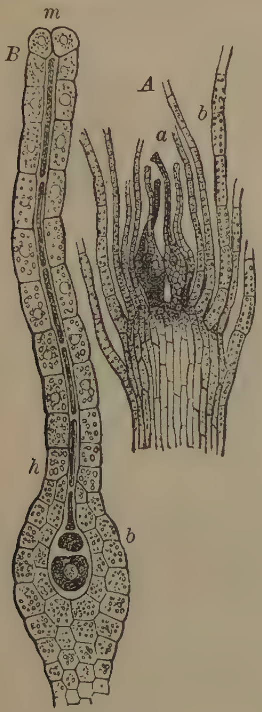


FIG. 203.

A, longitudinal section of summit of a small archegonium-bearing plant of *Funaria hyrometrica*, a moss; *a*, archegonia; *b*, leaves. *B*, an archegonium of the same moss; *m*, mouth; *h*, neck; *b*, enlarged portion, containing the oösphere. (*A* magnified 100 diameters; *B* magnified 550 diameters.)

FIG. 204.

A, a bursting antheridium of *Funaria hygrometrica*, a moss; *a*, the antherozoids; *B*, the antherozoids more strongly magnified, in the mother cell; *c*, antherozoid of pigeon-wheat moss (*Polytrichum*). (All much magnified.)

Sketch the uncovered urn, as seen through the magnifying glass, noting the little knob at its base and the circular lid.

Pry off this lid, remove some of the mass of spores from the interior of the urn, observe their color as seen in bulk through the magnifying glass, then mount in water, examine with the highest obtainable power of the microscope and sketch them. These spores, if sown on moist earth, will each develop into a slender, branched organism, consisting, like pondscum, of single rows of cells, Fig. 206, called the *protonema*.

FIG. 205. — Longitudinal Section of the Summit of a very Small Antheridium-Bearing Plant of *Funaria hygrometrica*, a Moss.

a, young antheridium; *b*, nearly mature antheridium; *c*, appendages growing among the antheridia; *d*, leaves cut through the midrib; *e*, leaves cut through the blade. (Magnified 300 diameters.)

295. *Other Reproductive Apparatus.* — The student cannot, without spending a good deal of time and making himself expert in the examination of mosses, trace out for himself the whole story of the reproduction of any moss. It is sufficient here to give an outline of the process. The protonema develops buds, one of which is shown in Fig. 206, and the bud grows into an ordinary moss plant. This plant, in the case of the pigeon-wheat moss, bears organs of a somewhat flower-like nature, Fig. 205, which contain either *antheridia*, Fig. 204, organs which produce fertilizing cells called *antherozoids*, or *archegonia*, Fig. 203, organs which produce *oöspheres* (§ 275), but in this moss antheridia and archegonia are not produced in the same "moss-flower." The plants therefore correspond to diœcious ones among flowering plants.

After the fertilization of the oösphere, by the penetration of antherozoids to the bottom of the flask-shaped archegonium, the development of the oösphere into an urn begins, the latter rises on its slender stalk, while the upper part of the archegonium is carried with it and persists for a time as the hood, Fig. 202, *c*.

MOSSES.

296. *Mosses have Specialized Organs.* — In his examination of a moss the student at once recognizes it as a distinct advance from the kind of plant life exemplified by any of the cryptogamous types which he has previously studied. Root, stem, and leaf, as found in flowering plants, are represented by organs of similar function, though not of similar structure to true roots, stems, and leaves. The principle of *physiological division of labor*, so characteristic of the higher plants, is fairly exemplified in mosses. Although destitute of true flowers, they possess flower-like organs which may be either monœcious or diœcious.

297. *Alternation of Generations.* — In mosses, as in the simpler liverworts, below them, and the more complex ferns, above them, the reproductive process includes what is known as an *alternation of generations.* That is to say, the organs of reproduction produce a spore which does not grow directly into a new individual like the parent. The fertilized oösphere

produces the urn or spore-capsule, and this is really a new plant. It remains attached to the parent plant and is nourished by it, does not grow to any considerable size, but develops a great number of spores in its interior. These spores when fully formed are set free, germinate, and produce a thread-like protonema, which at length grows into the fully developed moss plant. The two generations, then, are the moss, with its rather complicated reproductive apparatus, and the urn,

FIG. 206.

B, protonema of *Funaria hygrometrica*, a moss; *h*, a well-developed primary shoot; *K*, rudiment of a leaf-bearing axis, or ordinary moss plant, like Fig. 202; *w*, a root-hair. (Magnified about 90 diameters.)

destitute of such apparatus but filled with spores which are merely the product of continued cell-division in the interior of the spore-capsule.

298. *Nutrition in Mosses.* — Mosses, like the higher plants, draw their food supply partly in a liquid form from the earth and partly in a gaseous form from the air. It is interesting to notice, in passing, that one of the best plants with which

to illustrate the process of setting free oxygen, which accompanies fixation of carbon (§ 149), is an aquatic moss.[1]

THE STUDY OF A FERN.[2]

299. *Conditions of Growth.* — If the specimens studied were collected by the class, the collectors should report exactly in regard to the soil and exposure in which the plants were found growing. Do any ferns occur in surroundings decidedly different from these? What kind of treatment do ferns need in house culture?

300. *The Underground Portion.* — Dig up the entire underground portion of a plant of lady-fern. Note the color, size, shape, and appendages of the rootstock. If any are at hand which were collected in their late winter or early spring condition, examine into the way in which the leafy parts of the coming season originate from the rootstock, and note their peculiar shape. This kind of vernation is decidedly characteristic of ferns. Observe the number and distribution of the roots along the rootstock. Bring out all these points in a sketch.

301. *The Frond.* — Fern leaves are technically known as *fronds.* Observe how these arise directly from the rootstock.

Make a somewhat reduced drawing of the entire frond, which consists of a slender axis, or *rhachis*, along which are distributed many leaflets or *pinnæ*, each composed of many *pinnules*. Draw the under side of one of the pinnæ, from near the middle of the frond, enlarged to two or three times its natural size, as seen through the magnifying glass. Note just how each pinnule is attached to its secondary rhachis.

Examine the under side of one of the pinnules (viewed as an opaque object without cover-glass) with the lowest power of the microscope, and note:

(*a*) The "fruit-dots" or *sori* (already seen with the magnifying glass, but now much more clearly shown).

(*b*) The membranous covering or *indusium* of each sorus. Observe how this is attached to the veins of the pinnule. In such ferns as the common brake (*Pteris*) and the maiden-hair (*Adiantum*) there is no separate indusium, but the spore-cases are covered by the incurved edges of the fronds.

[1] Fontinalis.

[2] The outline here given applies exactly only to *Asplenium filix-fœmina.* Any species of *Asplenium* or of *Aspidium* is just as well adapted for study. *Cystopteris* is excellent, but the indusium is hard to find. *Polypodium vulgare* is a simple and

(*c*) The coiled spore-cases or *sporangia*, lying partly covered by the indusium. How do these sporangia discharge their spores?

Make a drawing, or several drawings, to bring out all these points.

Examine some of the sporangia, dry, with a power of about 50 or 75 diameters, and sketch. Scrape off a few sporangia, thus disengaging some spores, mount the latter in water, examine with a power of about 200 diameters, and draw.

302. *Life History of the Fern.* — When a fern-spore is sown on damp earth it gradually develops into a minute, flattish object, called a *prothallium*, Fig. 208. It is a rather tedious process to grow prothallia from spores, and the easiest way to get them for study is to look for them on the earth or on the damp outer surface of the flower-pots in which ferns are growing in a greenhouse. All stages of germination may readily be found in such localities.

Any prothallia thus obtained for study may be freed from particles of earth by being washed, while held in very small forceps, in a gentle stream of water from a wash-bottle. The student should then mount the prothallium, bottom up, in water in a shallow cell, cover with a large cover-glass, and examine with the lowest power of the microscope. Note:

(*a*) The abundant root-hairs, springing from the lower surface of the prothallium.

(*b*) The variable thickness of the prothallium, near the edge consisting of only one layer of cells.

(*c*) (In some mature specimens) the young fern growing from the prothallium, as shown in Fig. 208, *B*.

The student can hardly make out for himself, without much expenditure of time, the structure of the *antheridia* and the *archegonia*, by the coöperation of which fertilization takes place on much the same plan as that already described in the case of mosses. The fertilized *oösphere* of the archegonium gives rise to the young fern, which grows at first at the expense of the parent prothallium but soon develops roots of its own and leads an independent existence.

The mature fern makes its living, as flowering plants do, by absorption of nutritive matter from the soil and from the air, and its abundant chlorophyll makes it easy for the plant to decompose the supplies of carbonic acid gas which it takes in through its stomata.

generally accessible form, but has no indusium. *Pteris aquilina* is of world-wide distribution, but differs in habit from most of our ferns. The teacher who wishes to go into detail in regard to the gross anatomy or the histology of ferns as exemplified in *Pteris* will find a careful study of it in Huxley and Martin's *Biology*, or a fully illustrated account in Sedgwick and Wilson's *Biology*.

FIG. 207. — A Fern (*Aspidium Filix-mas*).

1, general view of the plant; *a*, young fronds unrolling; 2, cross-section of the rootstock, showing fibro-vascular bundles, *a a*; 3, a pinnule with fruit-dots; *a a*, indusium; *b*, spore-cases; 4, vertical section through 3 *a*; 5, vertical section at right angles to that of (4), showing: *a*, section of pinnule of leaf; *b*, section of indusium; *c*, spore-cases; 6, a single spore-case, with its stalk, *a*, and its elastic ring, *c*, discharging spores at *d*. (1 is reduced to about $\frac{1}{5}$ natural size; 2, 3, are slightly magnified; 4 is more magnified; 5, 6 are considerably magnified.)

FERNS.

303. *Structure, Form, and Habits of Ferns.* — The structure of ferns is much more complex than that of any of the groups of cryptogamous plants discussed in the earlier portions of the present chapter. They are possessed of well defined fibro-vascular bundles, they form a variety of parenchymatous cells, the leaves have a distinct epidermis and are provided with stomata.

Great differences in size, form, and habit of growth are found among the various genera of ferns. The tree ferns of

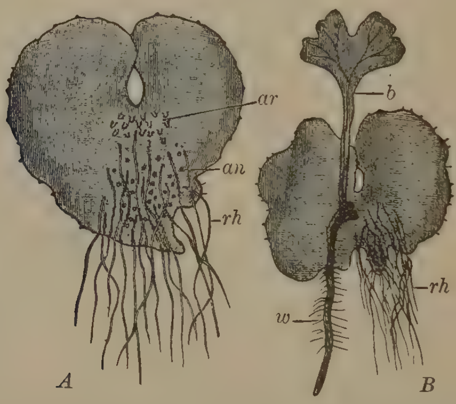


FIG. 208. — Prothallia of a Fern (*Aspidium Filix-mas*).

A, lower side of prothallium; *ar*, archegonia; *an*, antheridia; *rh*, root-hairs; *B*, prothallium producing a young fern plant; *b*, the first leaf; *w*, the root. (Magnified about 8 diameters.)

South America and of many of the islands of the Pacific ocean sometimes rise to a height of forty feet, while the most minute species of temperate and colder climates are not as large as the largest mosses. Some species climb freely, but most kinds are non-climbing plants of moderate size, with well developed rootstocks, which are often, as in the case of

the bracken-fern, or brake,[1] and in *Osmunda*, very large in proportion to the parts of the plant visible above ground.

304. *Economic Value of Ferns.* — Ferns of living species have little economical value, but are of great interest, even to non-botanical people, from the beauty of their foliage.

During that vast portion of early time known to geologists as the Carboniferous Age the earth's surface in many parts must have been clothed with a growth of ferns more dense than is now anywhere found. These ferns, with other flowerless herbs and tree-like plants, produced the vegetable matter out of which all the principal coal-beds of the earth have been formed.

305. *Reproduction in Ferns.* — The reproduction of ferns is a more interesting illustration of alternation of generations than is afforded by mosses. The fruiting plant is the minute prothallium, and the non-fruiting plant, which we commonly call the fern, is merely an outgrowth from the fertilized oösphere, and physiologically no more important than the urn of a moss, except that it supplies its own food instead of living parasitically. Like this urn, the fern is an organism for the production of unfertilized spores, from which new plants endowed with reproductive apparatus may grow.

306. *Relation of Reproduction in Ferns to that in Flowering Plants.* — Botanists have been able to trace out in great detail the true relation which such forms of reproduction as occur in mosses and in ferns bear to that of flowering plants. Stated in the merest outline their conclusions are that the nucleated ovule cell or egg-cell (*e*, Fig. 142) which is fertilized by the pollen tube corresponds to the oösphere, and that part of the contents of the pollen-grain corresponds to the antherozoid.[2]

[1] *Pteris aquilina.*

[2] See Strasburger, Noll, Schenk, and Schimper, *Lehrbuch*, pp. 372–376, and Potter's Warming's *Systematic Botany*, pp. 234–250.

APPENDIX A.

THE USE OF THE COMPOUND MICROSCOPE.

The Instrument. — For elementary class work, a low-priced but strong and well-made instrument is needed. Several of the European makers furnish excellent instruments for use in such a course as that here outlined. Among these are the Leitz microscopes, which are furnished by Wm. Krafft, 411 West 59th St., New York City, and those of Nachet, sold by the Franklin Educational Co., 15 and 17 Harcourt St., Boston. The Leitz stand, No. IV, can be furnished duty free (for schools only), with objectives 1, 3, and 5, eye-pieces I and III, for $24.50. If several instruments are being provided, it would be well to have part of them equipped with objectives 3 and 7, and eye-pieces I and III. The best form of camera lucida for this microscope costs (duty free) $7.80.

The American manufacturers, Bausch & Lomb Optical Company, Rochester, N. Y., and No. 130 Fulton Street, New York City, have recently produced a microscope of the Continental type which is especially designed to meet the requirements of the secondary schools for an instrument with rack and pinion coarse adjustment and serviceable fine adjustment, at a low price. They furnish this new stand, "AAB," to schools and teachers at "duty-free" rates, the prices being, for the stand with two eye-pieces (any desired power), $\frac{2}{3}$-inch and $\frac{1}{4}$-inch objectives, $25.60, or with 2-inch, $\frac{2}{3}$-inch and $\frac{1}{4}$-inch objectives, and two eye-pieces, $29.20.

Stand "A," the same stand as the "AAB," without joint and with sliding tube coarse adjustment (as in the Leitz Stand IV), and with three eye-pieces and $\frac{2}{3}$-inch and $\frac{1}{4}$-inch objectives, is furnished for $20.40. Stand "A," with two eye-pieces, $\frac{2}{3}$-inch and $\frac{1}{6}$-inch objectives, $20.40.

Class Use of the Microscope. — If the class works in a special laboratory in small divisions (not more than twelve), the teacher can examine the preparation of the object, the focusing of the instrument,

and the sketch which the pupil is making, — all while the work is going on. But if the class unfortunately consists of from twenty-five to forty pupils, in an ordinary recitation room, a good deal of ingenuity will be needed to secure results of any value.

The microscopes with the prepared objects should be placed upon the desks or tables which are best lighted.

If there are several instruments it will usually be found preferable to use all of them during any given recitation upon preparations of the same object, but to have some provided with lower and others with higher powers.

It is important to have a card attached to each microscope stating what object is upon the stage and what magnifying power is given by the combination in use. The class may sometimes be divided and half, or less than half, be allowed to work with the microscope while the rest are engaged in written or oral recitation, or in examining the grôss anatomy of the seed, root, stem, etc. Each student should be required to take his note-book to the microscope and draw while at the instrument.

Several of the best sketches may be put on the board toward the end of the hour, and a composite drawing finally made, embodying the best portions of each. A still better plan is to have posted at the last a drawing which the instructor has prepared beforehand (best with the aid of the *camera lucida*, or from a photo-micrograph), and if desirable to have this copied by the class. The object sought should be to make the pupils see as much as possible for themselves, but to make sure before leaving the object that they see it as it really is.

Magnifying Power. — The lowest magnifying power which will show the desired structure is to be preferred, both because this admits of the best illumination and because an average focusing which will suit most of the eyes in the class can be secured with objectives of $\frac{1}{2}$-inch or longer focus, but not with higher powers. Constant use should be made of the $1\frac{1}{2}$-inch or 2-inch objective to give general views of the object. A double nose-piece with 2-inch and $\frac{1}{2}$-inch, or 1-inch and $\frac{1}{4}$-inch objectives attached will save much time and trouble.

The class may best be made to understand the meaning of the

term magnifying power by examining the same simple object as seen with several powers. For instance, a letter of ordinary print (*e.g.*, the finest used in this book), may be examined with the naked eye and with the magnifying glass. Then sketches on cardboard may be handed round to show the size of the object, drawn with the camera lucida as seen under the 2-inch objective, with others drawn to scale, to show the effect of all the other magnifying combinations which the microscopes belonging to the school afford.

For further suggestions in regard to the manipulation and use of the microscope the teacher is referred to any of the standard works on the subject. The little book of Charles H. Clark, cited in the bibliography (Appendix D), is compact and usable.

An important adjunct to the microscopical work (or, if need be, a partial substitute for it) consists in the use of photomicrographs of the most important tissues. The mounted silver-prints, or unmounted blue-prints, may be numbered and given out to the division for study at the desk *after the structure in question has been studied with the microscope.* Ample time should be given for careful examination of the pictures thus given out, and then the members of the division may be questioned individually on the photographs, or a written exercise may be set, in which all shall write as fully as possible about a designated number of the photomicrographs examined. The teacher will find that the prints differ just enough from the somewhat diagrammatic or idealized cuts usually given in books to afford an admirable opportunity for the pupil to exercise his powers of observation and discrimination in making out the exact nature of the several tissue elements to be found in each photograph.

APPENDIX B.

APPARATUS AND REAGENTS.

Requisites for each Student. — Every member of the class should have:

Two or three mounted needles. (Prepared by forcing fine needles, eye foremost, into round slender sticks, *e.g.*, old penholders.)

A sharp penknife or a scalpel.

A pair of small steel forceps.

A good magnifying glass; Coddington lenses are excellent, but rather expensive. The ordinary tripod magnifier which costs at wholesale 30 or 40 cents will answer fairly well.[1]

A large note-book of unruled paper for drawing.

A drawing pencil.

A ruled note-book for record of experiments, etc.

General Equipment of Apparatus. — Compound microscopes, as described in Appendix A.

It is desirable to have one for the use of each member of the division. Usually it is not possible to secure nearly as many instruments as this. Much good work may be done with only one or two microscopes, but in this case the microscopical work will have to be done partly out of the regular class hour and part of it must be carried along while the class as a whole is doing other than microscopical work.

A set of photomicrographs of some of the most important tissues described in the text, or of similar ones.

Mr. W. H. Walmsley, 4248 Pine Street, Philadelphia, Pa., who bears a national reputation for the excellence of his photomicrographs, and has lately given much attention to botanical work, has undertaken to prepare a set of 24 negatives to illustrate the set of microscopic prepa-

[1] An achromatic doublet, made by Leitz, superior to the Coddington lens, can be imported duty free for $2. It magnifies 8 times.

rations described on pages 256, 257. The subjects chosen are slides 1, 2, 3, 4, 5, 7, 8, 9, 11, 13, 14, 16, 17, 20, 21, 22. A price-list of these photomicrographs, together with many hundreds of others on botanical subjects, will soon be issued by Mr. Walmsley, who will meantime furnish the set above mentioned to teachers who wish them. Among the other botanical photomicrographs which Mr. Walmsley has in stock are those of starches, pollen, sections of woods and stems, ovaries (sections), spiral and annular vessels, leaf-sections, stomata, leaf-scales and hairs, mosses (entire), algæ (marine and fresh-water), fungi.

Miss E. M. Drury, 45 Munroe Street, Roxbury (Boston), Mass., will furnish photomicrographs of the same set of 24 (from Mr. Walmsley's negatives). Her prices will be: for unmounted blue-prints, $0.85 per dozen; for mounted silver-prints, $2.00 per dozen.

A small balance.

The hand-scale with 5-inch beam and set of weights from .01 gram to 20 grams, furnished by Eimer & Amend of 205–211 Third Avenue, New York, for about $2, is good enough.

A trip-scale.

The "Harvard trip-scale," furnished by the Fairbanks Scale Co., for about $5.70, is well adapted for weighing potted plants for transpiration experiments, etc.

A cylindrical graduate of 250 to 500 cubic centimeters capacity.

One or two large bell glasses.

Inexpensive one and two quart battery jars for use in cultivating potted plants, — for transpiration experiments. (Earthen flower-pots are not so good, because they permit too much evaporation through their sides.)

Six or eight-quart dishes for germination experiments.

Wide-mouthed bottles.

Glass cylinders of about 300 cubic centimeters capacity for water cultures.

A section-knife, or a razor, flat-ground on one side, hollow-ground on the other.

An Arkansas oilstone.

Watch-glasses.

Glass-stoppered reagent bottles.

Assorted corks and rubber stoppers.

Microscope slides.

Thin glass covers.

Thin sheet rubber, such as is used by dentists, in pieces about 24 inches square (this is not needed if the teacher prefers to use sheet lead in the transpiration experiment; see page 115).

General Reagents and other Supplies. — Alcohol, commercial, 95%.

Alcohol, absolute, a few ounces only.

Hæmatoxylin solution.[1]

Canada balsam.

Caustic potash solution, one part of solid caustic potash in 20 parts distilled water.

Nitric acid, concentrated.

Red ink.[2]

Potassium chlorate.

Fehling's solution, test for grape sugar. This reagent may best be bought of the wholesale druggist or dealer in chemicals. It may be prepared by dissolving 34.64 grams pure crystallized cupric sulphate in 200 cubic centimeters water and mixing the solution with 150 grams neutral potassic tartrate, dissolved in about 500 cubic centimeters of a 10-per-cent solution of sodium hydrate. The whole is then to be diluted with water to 1 litre and 100 cubic centimeters glycerine added.

Millon's reagent for proteids. Prepared by dissolving 1 part by weight of mercury in 2 parts of nitric acid of sp. gr. 1.42 and then diluting with twice its volume of water.

Preservative fluid, prepared by dissolving 20 parts by weight of chrome alum and 5 parts formalin in 975 parts of water. This serves to preserve (although it may discolor) portions of leaves, stems, rootstocks, roots, fruits, etc., which it is desirable to keep in a moist condition, and is much cheaper than alcohol. One part formalin to 40 of water by volume makes a still better preservative

[1] It is cheaper to buy this than to make it.

[2] As considerable quantities of this are to be used (especially if it is issued to the class for home work), if it cannot be bought very cheaply the instructor may make it for himself by dissolving eosin in water. Eosin costs by the pound from $1.65 to $2. An ounce will make as much as two quarts of red ink.

fluid, since it does not alter the natural colors of most objects kept in it.

Pure glycerine.

Glycerine and distilled water, equal parts.

Carbolic acid crystals.

Carbolic acid, 2-per-cent solution.

Iodine solution, prepared by dissolving 4 grams potassium iodide in 40 cubic centimeters distilled water, adding 1 gram iodine, and, when it is entirely dissolved, diluting the solution to 1000 cubic centimeters.

Syrups of various strengths for pollen-tube production, made by dissolving ordinary granulated sugar in boiling-hot distilled water. The water should be weighed cold, then heated in a flask and the weighed amount of sugar added. It will be found less troublesome to weigh out the required amounts in this way than to make a saturated solution and dilute it. Syrups of 2, 5, 10, 15, 25, and 30 per cent sugar will furnish range enough for experiment. If they are kept in glass-stoppered bottles which have been rinsed out with chromic acid solution and then with distilled water, the syrup will keep for months.

Ammonium nitrate, 4-per-cent solution. This may be added in small quantities to potted plants as a fertilizer.

Ether, commercial, for extraction of oil from seeds. (Benzine is cheaper and will answer nearly as well.)

Sand, pine-sawdust, blotting-paper, for germination of seeds. Grafting-wax.

Botanical apparatus and laboratory supplies of every description, including material for study, will be furnished by the Cambridge Botanical Supply Co., 1284 Massachusetts Ave., Cambridge, Mass.

APPENDIX C.

MATERIAL FOR STUDY.

Chapter I. — Squash-seeds, beans, peas, sunflower-seeds.

Chapter II. — Barley, red-clover-seed, seedlings of several kinds, 2–6 inches high, growing in earth, sand, or sawdust.

Chapter III. — Sprouted peas, clover-seed, four-o'clock-seed, Indian corn, boiled green corn in alcohol, bean seedlings 3 weeks old, ground flaxseed, soaked corn, corn meal, flour, oatmeal, buckwheat flour, rye flour, sunflower-seeds, peanuts, Brazil nuts.

Chapter IV. — Cuttings of Wandering Jew (*Tradescantia zebrina*), corn-stalks with roots, water-hyacinth, microscopic sections of roots,[1] parsnips, dahlia roots or sweet potatoes, begonia leaves.

Chapter V. — Twigs of horse-chestnut, hickory, beech, etc., with winter buds, potatoes, onions, rootstocks of iris, sweet flag, or sedges (best in preservative fluid).

Chapter VI. — Apple twigs, fresh or in preservative fluid, hickory or white-oak twigs of three or more years old, set of Hough's thin sections (footnote, p. 53), billets of as many kinds of native wood as are obtainable (with the ends planed smooth and split through the pith), cylinders from three or four year old hickory, or elm twigs, thin sections (see list at end), corn-stalk (in preservative fluid), palmetto, rattan, bamboo, asparagus.

Chapter VII. — Fresh shoots of grapevine, twigs of oak, ash, or elm, fuchsia growing in a flower-pot, microscopic sections (see list at end), potatoes, onions.

Chapter VIII. — Twigs with winter buds of horse-chestnut, hickory, beech, tulip tree, lilac. A cabbage, a Bryophyllum leaf.

Chapter IX. — Leafy twigs of elm and maple, a variety of netted-veined and some parallel-veined leaves.

[1] See list at end of Appendix C.

Chapter X. — Potted plants of oxalis and sensitive plants, sunflower seedlings a foot or more high to show movement of leaves to secure sunlight.

Chapter XI. — Droseras and Sarracenias, potted and growing under bell glass, a cactus, a houseleek or an aloe, an Echeveria or a Cotyledon.

Chapter XII. — Fresh lily leaves, microscopical preparations (see list at end), fresh hydrangea or cucumber leaves, potted hydrangeas and rubber plants (§ 144), leaves of lettuce, hydrangea, maple, hickory, or cucumber (§ 145), Elodea, Fontinalis, Spirogyra, etc. (footnote to § 149), growing nasturtium plants, early summer and late fall leaves of trees in alcohol.

Chapter XIII. — Fresh flowers of any species of Tradescantia, or living Chara or Nitella in water.

Chapter XIV. — Flower-clusters of various kinds.

Chapter XV. — Flowers of trillium, tulip, or buttercup.

Chapter XVI. — Imperfect flowers, as those of willow, poplar, walnut, birch, hazel, begonia.

Chapter XVII. — Fresh pollen of Cytisus, sweet pea, or nasturtium, mounted slide of pollen (see list at end).

Chapter XVIII. — Flowers of hazel, alder, pine grasses (wind-fertilized), insect-fertilized flowers from list in § 211.

Chapter XIX. — Fruits of tomato, lemon, bean, dock.

Chapter XX. — Fruits of ash, elm, or maple, of milkweed, of burdock, cocklebur, or beggar's ticks (*Bidens*), of cherry, or strawberry.[1]

Chapter XXIII. — Protococcus (or Pleurococcus). Living specimens are best, but mounted slides will answer. Living Spirogyra, mounted slides of Spirogyra in conjugation, desmids (fresh or mounted), growing yeast, black mould growing, a mounted slide of zygospores of Mucor, Polytrichum in various stages of growth, a mounted slide of some moss protonema, whole fern plants (including rootstocks), fruiting fern fronds, fern prothallia (fresh, or mounted for the microscope).

[1] Professor Byron D. Halsted, Rutgers College, New Brunswick, New Jersey, will furnish sets of 100 weeds and of 100 weed-seeds and fruits at $10 per set; $20 for the two sets.

List of Slides.[1]

1. Starch in cotyledons of bean.
2. Do. three weeks after germination.
3. Rootlet of "Chinese sacred lily," *Narcissus Tazetta*, variety *orientalis* (longitudinal section).
4. Rootlet of barley.
5.[2] Cross-section of exogenous root in its winter condition (starch).
6.[2] Do. of small parsnip.
7. Cross-section, longitudinal tangential section, and longitudinal radial section of apple wood (all on one slide).
8. Do. of grapevine.
9. Do. of sassafras.
10. Macerated wood cells and bast fibres.
11. Three sections of white pine (on one slide).
12. Longitudinal section of chicory or dandelion root (ducts, parenchyma).
13. Do. rootstock of Pteris (ducts, parenchyma).
14. Do. stem of Ricinus (ducts, parenchyma).
15. Section of elder pith.
16. Cross-section of young stem of clematis.
17. Cross-section of Indian corn stem.
18. [2] Do. of ash or beech twig in winter (storage of starch).
19. Lily leaf, cross-section and under epidermis (one slide).
20. Hydrangea leaf, lower epidermis.
21. *Ficus elastica* cross-section and lower epidermis (one slide).
22. Cross-section of leaf of rhododendron.
23. Cross-section of leaf of beech.
24. Pollen.
25. Protococcus.
26. Spirogyra in conjugation.

[1] This set of thirty-one mounted slides and the accompanying unmounted sections in alcohol will be furnished for $6 (or if mailed for $6 25) by Miss E. M. Drury, 45 Munroe Street, Roxbury (Boston), Mass. The price for single slides in this set varies from 25 to 50 cents per slide; other slides furnished to order.

[2] Fifty thin sections of each of these objects will be furnished in alcohol. They may be soaked in water for a few minutes, then moistened with dilute iodine solution and examined under the microscope for starch.

27. Zygospore formation of *Mucor Syzigites.*
28. Protonema of a moss.
29. Leaf of a moss (Mnium).
30. Prothallium of a fern.
31. Do. beginning to grow a young fern plant.

APPENDIX D.

REFERENCE BOOKS.[1]

Only a few of the books which the author regards as the most useful guides to elementary study and research in their several departments are here named. Both pupil and teacher will find it desirable to consult some of them frequently throughout the whole course of the botanical work. The starred titles (**) indicate books which will aid the teacher, but which the ordinary high-school pupil could hardly use. Where it is possible to discriminate, the best book, that is the book which combines accuracy, fullness, newness, and simplicity of statement to the highest degree, is placed first in its own list.

General Works.

Kerner and Oliver, *Natural History of Plants.* Blackie & Son, London, 1895. Henry Holt & Co., New York, 1895.

Strasburger, Noll, Schenk, and Schimper, *Lehrbuch der Botanik,*** *zweite Auflage.* Gustav Fischer, Jena, 1896.[2]

Vines, *Students' Text-Book of Botany,*** 2 vols. Macmillan & Co., New York, 1895.

Behrens, *Text-Book of General Botany.* Pentland, Edinburgh.

The Kerner and Oliver is a costly book, but is almost indispensable, since it goes over the greater part of the field of botany in a full and accurate, yet thoroughly simple and interesting way. The only criticism that can be urged against it is on the score of occasional fanciful statements, in regard to theories as yet unproved. The work by Strasburger and others is perhaps the best recent

[1] The author has been much aided in the preparation of this list by the one contained in Spalding's *Introduction to Botany*.

[2] A translation of this book will be issued by Macmillan & Co. The author has been obliged in the present book to refer to the second German edition of the *Lehrbuch*, since the English translation is not yet ready.

summary of botany in a moderate-sized octavo volume. Behrens's *Botany* is less recent, but very suggestive. All four books are profusely illustrated.

Laboratory Manuals.

Darwin and Acton, *Practical Physiology of Plants.* Macmillan & Co., New York, 1894.

Detmer, *Das Pflanzen-physiologische Practicum,*** *zweite Auflage.* Fischer, Jena, 1895.

MacDougal, *Experimental Plant Physiology.* Henry Holt & Co., New York, 1895.

Strasburger, *Practical Botany*, Macmillan & Co., New York, 1889; or better, *Kleines Botanisches Practicum,*** *zweite umgearbeitete Auflage*, Fischer, Jena, 1893.

Spalding, *Introduction to Botany.* D. C. Heath & Co., Boston, 1895.

Huxley and Martin, *Elementary Biology* (extended by Howes and Scott). Macmillan & Co., New York, 1892.

Clark, *Practical Methods in Microscopy.* D. C. Heath & Co., Boston, 1897.

Newell, *Outlines of Lessons in Botany*, Part I and Part II (2 vols.). Ginn & Co.

The first three of the books above mentioned are devoted to experiments in vegetable physiology. Detmer's is the best for those who can read German. Strasburger's book is devoted to vegetable histology and is excellent, though the translation by Hillhouse (of Strasburger's larger work) is less satisfactory than the *Kleines Botanisches Practicum.* Spalding's *Introduction* is not wholly a laboratory manual, though largely so. It supplies admirable directions for getting acquainted with plant life and structure at first hand. Huxley's *Biology* is partly devoted to animals, partly to plants. It gives excellent directions for the laboratory study of some of the lower forms of plant life.

Structural and Physiological.

Gray, *Structural Botany.* American Book Co.

Gregory, *Elements of Plant Anatomy.* Ginn & Co., 1895.

De Bary,** *Comparative Anatomy of the Phanerogams and Ferns.* Oxford, Clarendon Press, 1884.

Bessey, *Botany.* Henry Holt & Co., New York, 1888.

Thomé, *Structural and Physiological Botany.* John Wiley & Sons, New York, 1891.

Sachs, *Lectures on The Physiology of Plants.* Macmillan & Co., Oxford, Clarendon Press, 1887.

Gray's *Structural Botany* is written in an exceedingly clear and readable style. It is not brought down to date and it gives little histology; it is well supplemented by De Bary's work, and these two books, with the masterly lectures by Sachs, furnish a very full account of vegetable structure and life. Vines, *Physiology of Plants*, Cambridge, University Press, 1886, is more to be depended on in its chemical statements than the work of Sachs. Either Bessey's or Thomé's book furnishes a brief summary of anatomy and physiology.

Morphological.

Goebel, *Outlines of Classification and Special Morphology of Plants.*** Oxford, Clarendon Press, 1887.

Pax, *Morphologie der Pflanzen.*** Enke, Stuttgart, 1890.

Systematic.

Warming and Potter, *Handbook of Systematic Botany.*** Macmillan & Co., New York, 1895.

Engler and Prantl, *Die Natürlichen Pflanzenfamilien.*** Engelmann, Leipzig.

Le Maout and Decaisne, *Traite Général de Botanique.*** Firmin Didot Frères, Fils & Cie, Paris.

Vines, *Student's Text-Book* (see above).

Strasburger, Noll, Schenk, and Schimper, *Lehrbuch* (see above).

The first-named book in the list is clear, ably written, and sufficient for all ordinary purposes. Engler and Prantl's work in several volumes is a very large and elaborate one, not yet completed, with a wealth of illustrations. Le Maout and Decaisne's treatise is not modern, but is abundantly illustrated and will be found useful.

The work of Vines and that of Strasburger and others both contain outlines of systematic botany.

Floras, Etc.

Gray, *Field, Forest, and Garden Botany.* New edition by L. H. Bailey. American Book Co., 1894.

Gray, *Manual of Botany.* Sixth edition, revised. American Book Co.

Gray, *Synoptical Flora of North America.* American Book Co.

Chapman, *Flora of the Southern United States.* American Book Co.

Coulter, *Manual of the Botany of the Rocky Mountain Region.* American Book Co.

Miller and Whiting, *Wild Flowers of the Northeastern States.* G. P. Putnam's Sons, 1895. (Fully illustrated.)

Sargent, *The Silva of North America*** (in 12 vols., of which 8 have appeared; very fully illustrated). Houghton, Mifflin & Co., Boston.

Cryptogamic Botany.

Eaton, *Ferns of North America.*** Cassino, Boston, 1879.

Underwood, *Our Native Ferns and their Allies.* Henry Holt & Co., New York.

Macdonald, *Microscopical Examination of Drinking Water.* Lindsay and Blakiston, Philadelphia, 1875.

De Bary, *Comparative Morphology and Biology of the Fungi, Mycetozoa, and Bacteria.*** Oxford, Clarendon Press, 1887.

Bennett and Murray, *Handbook of Cryptogamic Botany.* Longmans, Green & Co., London and New York, 1889.

Goebel, *Outlines of Classification*, etc.** (See above.)

Warming and Potter, *Handbook*, etc.** (See above.)

The number of monographs on special topics in cryptogamic botany is too great to admit, in an elementary book, of even the mere mention of the most important titles. In the list above given, the works of Bennett and Murray and of Goebel are the only general ones, and in the former mention is made of a good many of the best special treatises on cryptogamic botany.

Relation of Plants to their Environment.

Müller, *The Fertilization of Flowers.* Macmillan & Co., London, 1883.

Darwin, *Insectivorous Plants.* D. Appleton & Co., New York.

Darwin, *The Power of Movement in Plants.* D. Appleton & Co., New York.

Darwin, *Animals and Plants under Domestication.* D. Appleton & Co., New York.

Geddes, *Chapters in Modern Botany.* Scribners, New York, 1893.

Lubbock, *Flowers, Fruits, and Leaves.* Nature Series, London.

Kerner, *Natural History of Plants.* (See above.)

Wiesner, *Biologie der Pflanzen.*** Wien, 1889.

Ludwig, *Lehrbuch der Pflanzenbiologie.*** Enke, Stuttgart, 1895.

Weed, *Ten New England Blossoms and their Insect Visitors.* Houghton, Mifflin & Co., Boston, 1895.

APPENDIX E.

THE NOTE-BOOK.

A good deal of the effectiveness of any course in botany which includes some laboratory work will depend on the way in which the note-book is kept.

It is better to have two books, one unruled, for drawing, the other ruled, for written notes.[1] All drawings and sketches should be made in such a way as to bring out (as far as the pupil understands them) the characteristic features of the organ or structure which is under investigation. A sketch in which a good deal of detail is omitted will, therefore, often be of more value than one in which the attempt is made to represent everything. Shading is in general to be avoided. The student will need constant admonition not to conventionalize what he sees, or to try to give general impressions. He would, if unguided, very likely represent the cross-section of coniferous wood, magnified 150 or 200 times, by a set of cross-hatchings, with the lines crossing at oblique angles, thus forming a set of very regular, diamond-shaped figures. The best antidote to this tendency is to confront the conventionalizer at every turn with a *camera lucida* drawing of the thing which he has just sketched, or (better still) with a photomicrograph.

The written notes should be kept in an orderly way; and the book which contains them needs to be indexed, day by day, as the work progresses. The writer feels convinced, as the result of a good many years of experience, that it is a mischievous practice to require pupils of secondary-school age to take any notes from rapid dictation. Matter which cannot be furnished in cyclostyle or hektograph copies to every pupil should be dictated orally, very slowly, or else posted

[1] An excellent note-book in which the pages are alternately ruled and blank, as recommended by Prof. W. F. Ganong of Smith College, is furnished by the Cambridge Botanical Supply Co.

on the board, or in a typewritten copy, to which the pupils may have free access during study-hours.

Frequent and unexpected examinations of the note-books by the teacher will do more than anything else to make pupils exact and painstaking in their record of work done. Much importance should be given to the valuation of the note-book in judging of the owner's progress in his work.

It is an unpardonable fault in the teacher to allow the notes to become mechanical, and it is therefore, in the writer's opinion, inadmissible to allow any set form of record to be followed throughout the study of any tissue or organ. The observations of the pupil may well be grouped in an orderly fashion during his first studies of leaves, for example, by following in the record some such form as that given in any of the best plant-analysis blanks, but it would be absurd to stretch the learner on such a Procrustes' bed more than once. It will go far toward training the pupil into a scientific habit of mind if he is required in his notes and in his recitations to distinguish clearly the sources of his knowledge. He should be able to state whether a given piece of information was derived from his own experiment or personal study of an object or a phenomenon, from an experiment performed by the teacher in the presence of the class, from outside reading, or from study of the text-book. Both note-books should throughout present constant evidence of the care with which their owner has kept account of the way in which he became possessed of the subject-matter which he enters in them. Drawings copied from the blackboard or from any book or photograph should be carefully labeled in such a way as to distinguish them from original ones.

INDEX AND GLOSSARY.

Part I.

PART II.

KEY AND FLORA.

EMBRACING A FEW OF THE COMMONEST SPRING FLOWERS OF THE NORTHERN AND MIDDLE STATES.

HOW TO USE PART II.

In order to determine an unknown species, the student is first to make a careful examination of the plant in hand. After noting in a general way the appearance of the root, stem, and leaf, including a cross-section of the stem, he should study the number, coherence, and adnation of the parts of the flower, then make and draw a cross-section and a lengthwise section of it. Irregularities in calyx or corolla, peculiarities in the shape, structure, or operation of the essential organs, such for instance as anthers discharging through chinks in the end, should be noted.

Next, the inquirer should look carefully through the Key to the Families. He is first to decide whether the plant in question is a Gymnosperm or an Angiosperm; if not a coniferous tree or shrub it will of course belong to the latter division. He is then to settle the question whether it is a Monocotyledon or a Dicotyledon, then under what division of the group the plant comes, and finally, to decide upon its Family.

Turning now to the page at which the family is described, a rapid inspection of the characteristics of the genera will make it evident to which one the species under examination belongs. It may not infrequently prove that none of the genera described agree with the plant studied, and in that case the student must either consult a larger flora or rest satisfied with having determined the family to which his specimen belongs.[1] The identification of the species, after

[1] It will greatly simplify matters if the teacher selects for examination only such species as are here described.

the genus has been reached, presents no difficulty in a little flora like the present one.

The author does not believe in spending much of the time of a class upon identifying species, but would rather recommend comparative studies of as many plants of a group as are accessible, and making these studies thorough enough to bring out fully the idea of the Family, the Genus, and the Species.[1] The descriptions in Part II of this book may be used as a check on the cruder ones which the pupil is first to frame for himself.

[1] The teacher will find abundant suggestions for such a course in Spalding's *Introduction to Botany*, pp. 152-260.

KEY TO SOME FAMILIES OF PHANEROGAMS.

GYMNOSPERMS. Ovules not enclosed in an ovary.

Trees or shrubs usually with needle-shaped, or scale-like, evergreen leaves and monœcious or diœcious flowers resembling catkins, the pistillate ones usually ripening into cones (Coniferæ), Pine Family, 7.

ANGIOSPERMS. Ovules in an ovary.

MONOCOTYLEDONS. Flowers generally on plan of 3 (never of 5).

GLUMACEOUS DIVISION. Flowers rudimentary, enclosed in husk-like bracts.

Bracts for each flower 2 (Gramineæ), stems cylindrical or nearly so, Grass Family, 9.

Bract for each flower 1 (Cyperaceæ), stems triangular, Sedge Family, 10.

SPADICEOUS DIVISION. Flowers clustered on a spadix (Araceæ), Arum Family, 11.

PETALOIDEOUS DIVISION. Flowers having a true perianth; not on a spadix.

Ovary free from perianth, stamens 6 (Liliaceæ), Lily Family, 12.

Ovary adnate to perianth.

Stamens 6 . . . . (Amaryllidaceæ), Amaryllis Family, 15.

Stamens 3 . . . . (Iridaceæ), Iris Family, 15.

Stamens 1 or (rarely) 2 . . (Orchidaceæ), Orchis Family, 16.

DICOTYLEDONS. Flowers generally on plan of 5 or 4.

APETALOUS. Flowers without corolla (sometimes also calyx wanting).

Flowers in catkins. Diœcious trees or shrubs; fruit, a pod (Salicaceæ), Willow Family, 17.

Flowers in catkins. Monœcious trees or shrubs; fruit, a nut (Cupuliferæ), Oak Family, 18.

Flowers not in catkins. (Here occur a few apetalous genera of certain polypetalous families.)

Stipules sheathing the stem at the nodes (Polygonaceæ), Buckwheat Family, 19.

Stipules not sheathing the stem, or absent; plants usually with a milky acrid juice (Euphorbiaceæ), Spurge Family, 31.

[Here come also Elms, some Maples, etc.]

POLYPETALOUS. Flowers having distinct petals.

Stamens on receptacle (hypogynous).

Numerous, and all floral organs distinct (Ranunculaceæ), Crowfoot Family, 22.

4 long and 2 short (sometimes fewer); petals 4 (Cruciferæ), Mustard Family, 24.

Few and definite; flowers regular . . . . (Caryophyllaceæ), Pink Family, 20.

5; flowers irregular . . . . (Violaceæ), Violet Family, 32.

Numerous and with the filaments united . . . . (Malvaceæ), Mallow Family, 31.

Stamens on calyx (perigynous).

Carpels fewer than sepals; leaves without stipules (Saxifragaceæ), Saxifrage Family, 26.

Carpels 2 or more (genus Prunus only one); leaves with stipules (Rosaceæ), Rose Family, 27.

Carpel 1 . . . . (Leguminosæ), Pulse Family, 29.

Stamens on ovary (epigynous) (Umbelliferæ), Parsley Family, 34.

[Near this come Evening Primroses, Cornels, and Gourds.]

GAMOPETALOUS. Petals united into a cup or tube. (A few have also distinct petals.)

Ovary free from calyx.

Corolla regular.

Ovary deeply 4-lobed . (Borraginaceæ), Borage Family, 39.

Ovary 2-celled, filled with ovules (Solanaceæ), Nightshade Family, 42.

[Near this are Morning-glories, Phloxes and Gentians.]

Ovary 1-celled, stamens opposite corolla-lobes (Primulaceæ), Primrose Family, 38.

Corolla irregular.

Ovary deeply 4-lobed . . . . (Labiatæ), Mint Family, 40.

Ovary entire, 2-celled (Scrophulariaceæ), Figwort Family, 43.

Corolla regular or irregular.

Ovary usually with as many cells as the corolla has lobes, anthers opening by a hole at the apex of each cell (Ericaceæ), Heath Family, 36.

Ovary adnate to calyx.

Stamens distinct, on corolla; leaves opposite, without stipules (Caprifoliaceæ), Honeysuckle Family, 46.

Stamens distinct, on corolla, leaves opposite, with stipules, or whorled without them . . . (Rubiaceæ), Madder Family, 44.

Stamens distinct, not on corolla (Ericaceæ), Heath Family, 36.

Stamens united by their anthers; flowers in heads (Compositæ), Composite Family, 48.

CLASS I. — GYMNOSPERMS.

Plants destitute of a closed ovary, style or stigma; ovules generally borne naked on a carpellary scale, which forms part of a cone. Cotyledons often several (Fig. 6).

CONIFERÆ, PINE FAMILY.

Trees or shrubs with wood of peculiar structure (Figs. 50, 51) destitute of ducts, with resinous and aromatic juice, leaves generally evergreen and needle-shaped or awl-shaped, and flowers destitute of floral envelopes, monœcious or diœcious, the staminate ones consisting of catkin-like spikes of stamens and the pistillate ones consisting of ovule-bearing scales, arranged in spikes which ripen into cones.

I. PINUS, PINE.

Sterile flowers somewhat resembling inconspicuous catkins, borne at the base of the young shoot of the season, each flower consisting of pollen-scales in spiral groups (Fig. 209, 2). Fertile flowers spikes which consist of spirally arranged carpel-scales, each scale springing from the axil of a bract and bearing at its own base two ovules (Fig. 209, 3). Fruit a cone, formed of the thickened carpellary scales, ripening the second autumn after the flower opened. Primary leaves, thin and chaffy bud-scales, from the axils of which spring the bundles of 2–5 nearly persistent, needle-like, evergreen leaves, from 1–15 in. long (Fig. 209, *d*).

a. (P. STROBUS), WHITE PINE. A tall tree, 75–160 ft. high, much branched and spreading when growing in open ground, but often with few or no living branches below the height of 100 ft. when growing in dense forests. Leaves clustered in fives, slender, 3–4 in. long, smooth, and pale or with a whitish bloom. Cones 5–6 in. long, not stout. The wood is soft, durable, does not readily warp, and is therefore very valuable for lumber.

b. (P. RIGIDA), NORTHERN PITCH PINE. A stout tree, 30–80 ft. high, with rough scaly bark. Leaves in threes, 3–5 in. long, stiff and flattened. Cones ovate-conical, 2–3 in. long, their scales tipped with a short, abruptly curved spine. Wood hard, coarse and resinous, mainly used for fuel.

FIG. 209.—Scotch Pine (*P. sylvestris*).

1, a twig showing: *a*, staminate catkins; *b*, pistillate catkins; *c*, a cone; *d*, needles. 2, an anther, *a*, side view; *b*, outer surface. 3, a carpel-scale, *a*, inner surface; *b*, outer surface. 4, a cone-scale, a seed-wing and a seed. 5, section of a seed, showing the embryo. (1) is natural size; the other parts of the figure are magnified by the amount indicated by comparison with the vertical line alongside each.

c. (P. SYLVESTRIS), SCOTCH PINE (wrongly called Scotch Fir). A medium-sized tree, with the older bark reddish and scaly. Leaves in twos, $1\frac{1}{2}$–$2\frac{1}{2}$ in. long. Cones rather small and tapering (Fig. 209, *c*). Cultivated from Europe.

II. LARIX, LARCH.

Flower-spikes short, opening in early spring, before the leaves; the fertile ones, while still young, of a beautiful crimson color. Fruit a small cone, with thin scales. Leaves, none of them scaly, but all needle-shaped, soft, deciduous, very numerous, in little brush-like bundles.

a. (L. AMERICANA), AMERICAN LARCH, TAMARACK, HACKMATACK (wrongly, but quite generally, called Cypress and Juniper). A tall, slender tree, 30–100 ft. high. Leaves slender and less than 1 in. long, very pale bluish-green. Cones $\frac{1}{2}$–$\frac{3}{4}$ in. long, few-scaled. Wood hard, tough, and heavy, of considerable use for ship-building.

b. (L. EUROPÆA), EUROPEAN L. Leaves bright green and longer; cones longer than in the preceding species and many-scaled. Cultivated from Europe.

CLASS II. — ANGIOSPERMS.

Plants with a closed ovary, in which the seeds are matured. Cotyledons 1 or 2.

SUB-CLASS I. — MONOCOTYLEDONOUS PLANTS.

Stems with the fibro-vascular bundles scattered amid the parenchyma cells (Fig. 54); in perennial plants no annual rings of wood. Leaves usually parallel-veined, alternate, nearly entire. Parts of the flower generally in threes (never in fives). Cotyledon one.

GRAMINEÆ, GRASS FAMILY.

Mostly herbs, with usually hollow stems, closed and enlarged at the nodes, alternate leaves, in two ranks, with sheathing bases, which are split open on the side opposite the blade. The flowers are nearly or quite destitute of floral envelopes, solitary, and borne in the axils of scaly bracts called *glumes*, which are arranged in two ranks overlapping each other on

1–many-flowered *spikelets;* these are variously grouped in spikes, panicles (Figs. 183, 211 *A*), and so on. The fruit is a grain (Fig. 9).

(The family is too difficult for the beginner, but the structure and grouping of the flowers may be gathered from a careful study of Figs. 210, 211.)

CYPERACEÆ, SEDGE FAMILY.

Grass-like or rush-like herbs, with solid, usually triangular, stems, growing in tufts. The sheathing base of the generally 3-ranked leaves, when present, is not slit as in grasses. The flowers are usually somewhat less enclosed by bracts than those of grasses; the perianth is absent or rudimentary; stamens generally 3; style 2-cleft or 3-cleft.

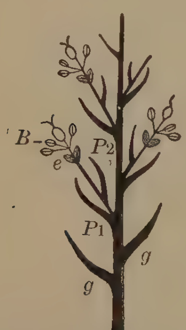


FIG. 210.—Diagram of Inflorescence of a Grass.
g, sterile glumes; P_1, a flowering glume; P_2, a scaly bract (palet): *e*, transparent scales (lodicules) at the base of the flower; *B*, the flower.

FIG. 211.—Fescue-Grass (*Festuca pratensis*).
A, spikelet (compare Fig. 210); *B*, a flower, the lodicules in front and the palea behind; *C*, a lodicule; *D*, ovary.

The general appearance of a common sedge may be learned from Fig. 33, and the flower-cluster and the flower understood from an inspection of Fig. 212.

The species are even more difficult to determine than those of grasses.

FIG. 212. — Inflorescence, Flower and Seed of a Sedge. (Great Bulrush, *Scirpus lacustris*.)

1, magnified flower, surrounded by a perianth of hypogynous bristles; 2, the seed; 3, section of the seed, showing the small embryo enclosed in the base of the albumen.

ARACEÆ, ARUM FAMILY.

Perennial herbs, with pungent or acrid juice, leaves often netted-veined, small flowers (perfect or imperfect) clustered along a peculiar fleshy spike called a spadix and frequently

more or less covered by a large hood-like bract called a spathe. Perianth, when present, of 4–6 parts; often wanting. Fruit usually a berry.

ARISÆMA, INDIAN TURNIP, DRAGON ROOT.

Spathe rolled up at base. Summit of spadix naked, the lower part flower-bearing, staminate flowers above and pistillate ones below. Stigma flat; ovary 1-celled; berry 1–few-seeded. Perennial herbs, springing from a corm or a tuberous rootstock.

a. (A. TRIPHYLLUM), INDIAN TURNIP, JACK-IN-THE-PULPIT. Leaves generally 2, each of 3 elliptical-ovate, pointed leaflets; spadix club-shaped, bearing usually only one kind of fully developed flowers, that is, full-sized pistillate and rudimentary staminate ones, or the reverse. Spathe much longer than the spadix and covering it like a hood. Corm turnip-like, but much wrinkled, starchy, and filled with intensely burning juice.

b. (A. DRACONTIUM), GREEN DRAGON, DRAGON ROOT. Leaf usually single, divided into 7–11 rather narrow pointed leaflets; spadix tapering to a long slender point, often bearing fully developed staminate and pistillate flowers.

LILIACEÆ, LILY FAMILY.

Mostly herbs. Flowers regular and symmetrical, nearly always with six stamens, with their anthers turned inwards. Ovary free, usually 3-celled. Fruit a capsule or berry. Seeds with endosperm (Fig. 8, I).

I. POLYGONATUM, SOLOMON'S SEAL.

Perianth tubular, with a 6-lobed margin; the 6 stamens inserted near the middle of the tube and included within it; anthers facing inward. Ovary 3-celled, each cell containing several ovules; style slender, included. Berry globular, black or blue, 3–6-seeded. Perennial herbs, with simple, alternate-leaved stems which proceed from large rootstocks, marked with circular scars, which show the points of attachment of stems of previous years. The common name is derived from the presence of these scars.

a. (P. BIFLORUM), SMALLER SOLOMON'S SEAL. Leaves minutely hairy underneath; stem slender, 1–3 ft. high; most of the peduncles 2-flowered.

b. (P. GIGANTEUM), LARGER SOLOMON'S SEAL. Smooth; stem stout and 2–7 ft. high; peduncles 2–8-flowered.

II. UVULARIA, BELLWORT.

Flowers yellow or yellowish, drooping, borne singly at the end of the forking stem. Perianth of 6 similar and separate narrow spatulate sepals, each grooved and nectar-bearing inside toward the base. Stamens 6, with linear anthers, which are much longer than the filaments. Style 3-cleft. Pod 3-lobed, 3-celled, few-seeded. Leaves alternate, broad and parallel-veined. Rootstocks short.

a. (U. GRANDIFLORA), LARGER BELLWORT. Leaves oblong, with the base clasping the stem so as to make it appear to run through the leaf a little way from the base; flowers greenish yellow, $1\frac{1}{2}$ in. long, anthers obtuse. A leafy plant, 1–2 ft. high.

b. (U. PERFOLIATA), MEALY BELLWORT. Leaves much as in the preceding species; flowers very pale yellow, with shining grains on the inner surfaces of the twisted sepals; anthers sharp-pointed; plant about $\frac{2}{3}$ the size of the preceding.

III. OAKESIA, WILD OATS.

Plants with much the aspect of the preceding genus, but with merely sessile leaves, triangular winged pods, and slender creeping rootstocks.

(O. SESSILIFOLIA), WILD OATS, STRAW LILIES. Leaves lance-oval, thin, smooth, pale beneath, $1–1\frac{1}{2}$ in. long; flower cream-color, nearly 1 in. long.

IV. ERYTHRONIUM, DOG-TOOTH VIOLET.

Perianth open bell-shaped, of six parts, with the tips recurved. Stamens 6, with flat awl-shaped filaments and erect anthers. Style rather long. Capsule obovate. No stem apparent above ground. Leaves two, long and smooth, tapering into petioles which arise from a pretty deeply buried bulb. The (commonly) single, nodding flower is borne on a long peduncle (scape), which arises from between the bases of the leaves.

a. (E. AMERICANUM), YELLOW ADDER'S-TONGUE. Leaves mottled; flowers handsome; perianth light yellow, style club-shaped; stigmas united.

b. (E. ALBIDUM), WHITE DOG'S-TOOTH VIOLET. Leaves not much mottled; perianth bluish-white; stigmas 3, short and spreading.

V. LILIUM, LILY.

Perianth more or less widely bell-shaped, colored, of 6 spreading distinct sepals, each with a nectar-bearing groove down the lower middle portion of its inner surface. Anthers attached near the middle to the pointed tip of the filament, and, when mature, swinging upon it. Style club-shaped; stigma 3-lobed. Capsule somewhat triangular, containing many seeds, arranged in two rows in each cell. Perennial herbs, with simple leafy stems, proceeding from scaly bulbs.

a. (L. LONGIFLORUM), LONG-FLOWERED WHITE LILY. 1–3 ft. high, with thick lanceolate leaves and a single pure white funnel-shaped flower 5–6 in. long. Cult., from China and Japan.

b. (Variety EXIMIUM), THE EASTER LILY, bears several very showy and sweet-scented flowers.

VI. TRILLIUM, BIRTHROOT.

Perianth of 6 parts, the 3 sepals unlike the 3 petals in color and in texture. Stamens 6, with the linear anthers usually opening inward, longer than the filaments. Stigmas 3, sessile, spreading at the tips. Ovary 3–6-angled, 3-celled, rather many-seeded. Low herbs with the stem springing from a short rootstock and bearing 3 large netted-veined leaves in a whorl and a large terminal flower.

a. (T. SESSILE), MOTTLED TRILLIUM. Leaves sessile, more or less ovate, acute, mottled; flower sessile; petals sessile, nearly erect, dull purple or greenish.

b. (T. ERECTUM), SQUAWROOT, BENJAMIN. Leaves broadly diamond-shaped, tapering to a short point, pedicel 1–3 in. long, not quite erect; petals ovate to lanceolate, much broader than the sepals, of a rich brownish purple or sometimes white or pale; stigmas distinct, stout, and spreading. The disagreeable scent of the flower has given rise to several absurd popular names for it.

c. (T. GRANDIFLORUM), often miscalled LILY. Leaves less broadly diamond-shaped, somewhat ovate; flower large and showy, with

oblanceolate petals sometimes $2\frac{1}{2}$ in. long, white, often becoming rose-tinted; stigmas nearly erect and somewhat coherent.

d. (T. CERNUUM), NODDING TRILLIUM. Leaves ovate-diamond-shaped, flowers not showy, borne on short pedicels, which are recurved beneath the leaves; petals ovate or broadly lanceolate, white or whitish; stigmas stout, separate, and recurved.

AMARYLLIDACEÆ, AMARYLLIS FAMILY.

Mostly smooth perennial herbs, sending up from a bulb a scape and linear root-leaves, which show no distinction between petiole and blade. Flowers nearly or quite regular. Stamens 6. Tube of the 6-parted, corolla-like perianth adnate to the 3-celled ovary. Capsule 3-celled, several–many-seeded.

NARCISSUS, NARCISSUS.

Flowers with a cup-shaped or other crown on the throat of the perianth; tube of the perianth somewhat cylindrical, the 6 divisions of the limb widely spreading. Stamens 6, inserted in the tube. Scapes with 1–several flowers from a thin dry spathe.

(N. PSEUDO-NARCISSUS), DAFFODIL, DAFFY, EASTER-FLOWER. Scape short, bearing 1 large yellow flower; tube of perianth short and wide, crown with a crimped margin. Cultivated from Europe.

IRIDACEÆ, IRIS FAMILY.

Herbs with equitant, 2-ranked leaves and usually showy perfect flowers enclosed by a sort of spathe composed of bracts. Tube of the perianth adnate to the ovary. Stamens 3, with anthers turned outwards. Style 1, stigmas 3, often petal like. Capsule 3-celled and many-seeded (Fig. 168).

I. IRIS, BLUE FLAG, FLOWER-DE-LUCE.

Sepals 3, reflexed, larger than the 3 erect petals. Stamens 3, distinct, borne on the sepals, anthers long and covered by the petal-like branches of the style (Fig. 167). Perennials, mostly with sword-shaped leaves and large rootstocks (Fig. 34).

(I. VERSICOLOR), BLUE FLAG. Stem 2–3 ft. high, rather stout. Flowers pretty large, blue, with green and yellow markings and purple veining. Pod large, triangular.

II. SISYRHINCHIUM, BLUE-EYED GRASS, STAR-EYED GRASS.

Perianth 6-parted, the spreading divisions all alike. Stamens monadelphous. Stigmas three-cleft, very slender. Small grass-like perennials with pretty, quickly withering flowers borne on slender scapes.

a. (S. ANGUSTIFOLIUM), SMALLER BLUE-EYED GRASS. Scape 4–12 in. high, usually unbranched and bearing a single cluster of blue flowers from a solitary spathe.

b. (S. ANCEPS), LARGER BLUE-EYED GRASS. Scape 6–18 in. high, usually branched, and bearing 2 or more spathes.

III. CROCUS, CROCUS.

Flowers sessile on the corm; tube of the perianth very long and slender, its divisions all alike or nearly so; stigmas 3-cleft; leaves proceeding from the corm.

(C. VERNUS), SPRING CROCUS. Stigmas short; flowers white, blue, or purple, leaves linear. Cultivated from Europe.

ORCHIDACEÆ, ORCHIS FAMILY.

Perennial herbs with perfect flowers (often extraordinarily irregular), perianth of 6 divisions, adnate to the 1-celled ovary, which contains an immense number of ovules. The stamens are one or two in number and united with the pistil; pollen of comparatively few grains held together in masses by cobweb-like threads.

The family is a difficult one, and most of the genera are so rare that specimens should not be collected in large numbers for class study. Two of the most familiar genera are *Cypripedium* or lady's slipper, and *Spiranthes* or lady's tresses. Many of the genera are tropical air-plants, like Fig. 13.

SUB-CLASS II.—DICOTYLEDONOUS PLANTS.

Stems composed of bark, wood, and pith; in woody stems which live over from year to year, the wood generally in annual rings, traversed at right angles by medullary rays. Leaves netted-veined. Parts of the flower usually in fours or fives. Cotyledons 2 (rarely none).

DIVISION I.

APETALOUS PLANTS. FLOWERS WITHOUT A COROLLA, OFTEN ALSO WITHOUT A CALYX.

SALICACEÆ, WILLOW FAMILY.

Diœcious trees or shrubs, with flowers in catkins (Figs. 108, 121), destitute of floral envelopes; fruit a 1-celled pod, with numerous seeds, provided with rather long and silky down, by means of which they are transported by the wind.

(Although the willow genus is easy to recognize, it is very hard to identify most of the species; many experienced botanists cannot do it.)

POPULUS, POPLAR, ASPEN.

Flowers borne in long, drooping catkins, which appear before the leaves; scales of the catkins irregularly cut toward the tip. Stamens 8–30 or more. Stigmas 2–4. Capsules opening early by 2 or 4 valves.

a. (P. TREMULOIDES), AMERICAN ASPEN, QUAKING ASP. A tree 20 to 60 ft. high, with greenish-white bark; leaves roundish heart-shaped, abruptly pointed, with small regular teeth. Leaf-stalk long, slender, and flattened at right angles to the broad surfaces of the leaf, causing it to sway edgewise with the least perceptible breeze.

b. (P. GRANDIDENTATA), LARGE-TOOTHED POPLAR. A tree 60 to 80 ft. high, with rather smooth gray bark; leaves 3–5 in. long,

roundish ovate and irregularly sinuate-toothed, when young completely covered with white silky wool, which is shed as soon as the leaf matures. The petiole is somewhat flattened, but not nearly as much so as that of the preceding species.

c. (P. MONILIFERA), COTTONWOOD. A large and very rapidly growing tree, 75 to 100 or more ft. in height, often with a markedly excurrent trunk (Fig. 26). Leaves large and broadly triangular, with crenate-serrate margins and long tapering acute tips; petioles long and considerably flattened. The numerous pediceled capsules are quite conspicuous when mature, and the air is filled with the downy seeds at the time when the capsules open.

CUPULIFERÆ, OAK FAMILY.

Monœcious trees or shrubs. Leaves alternate, simple, straight-veined, with deciduous stipules. The staminate flowers are generally in catkins, the pistillate ones sometimes in catkins, sometimes not. The ovary is several-celled, with one or two ovules in each cell, but only one ovule matures to form the fruit, which is a 1-celled and 1-seeded nut (Fig. 170).

I. BETULA, BIRCH.

Flowers opening in early spring, the staminate ones in long and drooping bright yellow catkins, which appear with or before the leaves, the pistillate ones in much shorter and stouter catkins. Each scale of the staminate catkins bears 3 flowers, which consist mainly of two 2-parted filaments, with an anther-cell on each. On every scale of the pistillate catkins are borne 2 or 3 flowers, each of which consists simply of a naked ovary with two diverging stigmas.

a. (B. LENTA), SWEET, BLACK, OR CHERRY BIRCH. Leaves and bark with the agreeable smell and flavor of wintergreen. Leaves more or less heart-shaped at the base, ovate or nearly so, doubly serrate. A tree 50 to 75 ft. high, with beautiful pale rose-colored wood, used in cabinet work under the name of red birch.

b. (B. POPULIFOLIA), GRAY BIRCH. Leaves triangular, with a long taper point and truncate base, unevenly twice serrate, with longish slender petioles, which allow the leaves to quiver like those of the aspen. Bark scaling off in white strips and layers, but not in nearly as large sheets as that of the rarer canoe birch (*B. papyrifera*).

A tall shrub or slender, straggling tree, 15–30 ft. high, seldom growing erect, often several trunks springing from the ground almost in contact and slanting away from each other.

c. (B. NIGRA), RIVER OR RED BIRCH. Leaves ovate diamond-shaped, acute at both ends, twice serrate. Twigs very slender and drooping (Fig. 28), brownish or cinnamon-brown when young. Bark of the larger limbs and trunk loose, shaggy, reddish-brown. A tree 30 to 50 ft. high.

II. CORYLUS, HAZELNUT.

Staminate flowers in slender drooping catkins, each flower consisting of 8 stamens with 1-celled anthers. Pistillate flowers several, grouped in a scaly bud, each consisting of a single ovary in the axil of a bract and with a smaller bract at each side; ovary somewhat 2-celled with 2 ovules, only one of which matures; stigmas 2, long and slender; nut roundish, hard-shelled, enclosed in a more or less fringed cup. Shrubs or small trees.

a. (C. AMERICANA), HAZELNUT. Leaves roundish heart-shaped; stipules acute, from a broad base; involucre open, showing the nut.

b. (C. ROSTRATA), BEAKED HAZELNUT. Leaves little, if at all, heart-shaped; stipules linear-lanceolate; involucre completely covering the nut and prolonged into a beak beyond it. (The latter species is not nearly as widely distributed as the former; they cannot be readily distinguished from each other until the fruit is somewhat mature.)

POLYGONACEÆ, BUCKWHEAT FAMILY.

Herbs with alternate, entire leaves and usually with sheathing stipules above the swollen joints of the stem. The apetalous flowers are generally perfect, with a 3–6-cleft calyx, generally colored and persistent. Fruit a compressed or 3-angled akene, enclosed in the calyx. Seeds with endosperm, which does not generally enclose the embryo. Stamens 4–12, on the base of the calyx.

I. RUMEX, DOCK, SORREL.

Calyx of 6 nearly distinct sepals, the three inner somewhat colored and in fruit enclosing the akene, 1 or more of them

generally with a little knob or tubercle on its outer surface. Stamens 6. Styles 3, short, stigmas much fringed to aid in wind-fertilization. Coarse herbs, some of them noxious weeds.

(R. CRISPUS), YELLOW DOCK. 3–4 ft. high, smooth, with large lanceolate or oblong leaves, strongly wavy-margined. Inner sepals round-heart-shaped, most of them tubercle-bearing.[1]

II. POLYGONUM, KNOTWEED.

Calyx generally of 5 colored or greenish sepals. Stamens 4–9. Styles short and thread-like, usually 3. Akene lens-shaped or triangular. Plants with stems enlarged at the joints, the latter covered with thin sheathing stipules. Flowers small, greenish, white, or reddish.

a. (P. AVICULARE), DOOR-WEED, DOOR-GRASS, WIRE-GRASS. Flowers axillary 2 or 3 together, minute and greenish; stems nearly prostràte; leaves varying from oblong to lanceolate.

b. (P. PERSICARIA), LADY'S THUMB, HEART-WEED, HEART'S-EASE. Flowers in dense ovoid or oblong spikes, with small, thin, dry bracts; calyx greenish-purple; stamens mostly 6; stems about 1 ft. high; leaves with a dark triangular or heart-shaped spot near the middle.

c. (P. SAGITTATUM), SCRATCH-GRASS, TEAR-THUMB. Flowers whitish, in small heads; stamens generally 8; stems 3–5 ft. long, climbing by the sharp, recurved prickles on the angles of the stem and midribs of the leaves; leaves short-petioled, arrow-shaped.

DIVISION II.

POLYPETALOUS PLANTS. FLOWERS WITH SEPARATE PETALS. (IN A FEW THE PETALS ARE WANTING.)

CARYOPHYLLACEÆ, PINK FAMILY.

Herbs with simple, entire, opposite leaves, symmetrical flowers on the plan of 4 or 5; stamens distinct, twice as many as the sepals, or fewer; styles usually 2–5; ovules

[1] In order to make the determination at the time of first flowering, the class would need also a supply of the fruit of this dock saved the preceding season.

generally many, borne at the base or on the axis at the centre of the (commonly 1-celled) pod.

I. DIANTHUS, PINK.

Calyx-tube cylindrical, with 2 or more bractlets overlapping it at the base. Petals 5, each consisting of a long claw and a notched or fringed limb. Stamens 10. Styles 2, recurved or spreading.

a. (D. BARBATUS), SWEET WILLIAM, BUNCH PINK. Leaves large, lanceolate or oblong-lanceolate; flowers of many colors, in large, showy, flat-topped clusters. Perennial, cultivated from Europe.

b. (D. PLUMARIUS), COMMON PINK, GRASS PINK. Leaves grass-like, with a whitish bloom; petals white, pink, or variegated, with the limb fringed; flowers solitary. Hardy perennials, cultivated from Europe.

c. (D. CARYOPHYLLUS), CARNATION, CLOVE PINK. Much like the preceding species, but with larger flowers; the broad petals merely crenate. Hot-house perennials (some hardy varieties), cultivated from Europe.

II. SILENE, CATCHFLY.

Calyx 5-toothed, without scales or bracts at the base, often much inflated. Stamens 10. Styles usually 3. Pod 1 or 3-celled, 3 or 6-toothed.

a. (S. CUCUBALUS), SNAPPERS, RATTLEBOX. Stems about 1 ft. high; leaves smooth, ovate-lanceolate; calyx bladdery, beautifully veined; petals white, 2-cleft. Perennial.

b. (S. PENNSYLVANICA), WILD PINK. Stems clustered, low (4–8 in.); root-leaves wedge-shaped or spatulate, those of the stem lanceolate; the medium-sized flowers clustered; petals wedge-shaped, notched, pink, with a crown at throat of corolla. Perennial.

c. (S. VIRGINICA), FIRE-PINK. Stems slender, erect, 1–2 ft. high, root-leaves spatulate, the upper leaves oblong-lanceolate; flowers few, peduncled, large and showy, bright crimson; corolla crowned. Perennial.

III. STELLARIA, CHICKWEED.

Sepals 5, connected at the base. Petals 5, 2-parted, rarely absent. Stamens 10 or fewer. Styles 3 or 4. Capsule egg-

shaped, many-seeded. Small herbs growing in damp or shaded places.

(S. MEDIA), COMMON CHICKWEED. Stems weak and procumbent, each traversed lengthwise by a hairy line; leaves ovate or oblong, the lower ones with hairy petioles; petals shorter than the sepals; stamens 3–10. Annual.

RANUNCULACEÆ, CROWFOOT FAMILY.

Mostly herbs, with colorless and usually acrid juice. Sepals 3–6. Petals 4–15, or absent. Stamens numerous, hypogynous. Pistils all distinct and unconnected with the perianth. Fruit consisting of numerous akenes (Fig. 169), of several follicles (Fig. 171), or sometimes of berries. Leaves without stipules, often clasping at the base (Fig. 170), frequently much cut or divided.

I. ANEMONE, ANEMONE, WIND-FLOWER.

Sepals few or numerous, colored and petal-like; petals usually wanting; akenes pointed, or with long, feathery tails. Perennial herbs, with radical leaves, and 2 or 3 opposite or whorled stem-leaves, constituting an involucre some distance below the flower or flower-cluster.

a. (A. CYLINDRICA), LONG-FRUITED ANEMONE. Plant about 2 ft. high, branching, with an involucre of long-petioled, divided and cleft leaves, from within which spring several long naked peduncles. Flowers greenish-white. Head of fruit cylindrical, composed of very many densely woolly akenes.

b. (A. NEMOROSA), WIND-FLOWER, WOOD ANEMONE. Stem simple, from a thread-like root-stalk; involucre of 3 leaves, each petioled, and of 3 leaflets, which are cut, toothed, or parted; peduncle 1-flowered; sepals 4–7, white, often tinged with bluish outside; carpels 15 or 20.

II. HEPATICA, LIVERLEAF, LIVERWORT, NOBLE LIVERWORT.

Involucre of 3 small simple leaves, so close to the flower as to look like a calyx. Leaves all radical, heart-shaped,

thick, and evergreen. Flowers single, on rather slender hairy scapes.

a. (H. TRILOBA), ROUND-LOBED HEPATICA. Lobes of the leaves obtuse or rounded; those of the involucre obtuse; sepals 6–12, varying from blue to white.

b. (H. ACUTILOBA), SHARP-LOBED HEPATICA. Closely similar to the former, except for the acute lobes of the leaves and tips of the involucre.

III. RANUNCULUS, CROWFOOT, BUTTERCUP.

Sepals 5. Petals 5, each with a little nectar-secreting scale or gland at the inside of the base. Akenes in a head, numerous, usually flattish. Stem-leaves alternate, the bases often clasping. (Fig. 70.) Flowers generally yellow.

a. (R. ABORTIVUS), SMALL-FLOWERED CROWFOOT. Very smooth and slender; the first root-leaves crenate; petals pale yellow, even shorter than the small reflexed calyx.

b. (R. RECURVATUS), HOOKED C. Hairy, 1–2 ft. high; leaves all long-petioled, 3-cleft and with wedge-shaped, 2–3-lobed divisions; akenes with long, recurved beaks; petals pale, shorter than the reflexed calyx.

c. (R. SEPTENTRIONALIS), CREEPING BUTTERCUP. Low, with ascending stems, especially in wet ground, sending out runners during the summer, but flowering on more or less upright shoots in spring; leaves 3-divided, with wedge-shaped or ovate divisions; flowers yellow, rather large and showy.

d. (R. BULBOSUS), BULBOUS BUTTERCUP, EARLY BUTTERCUP. Stem upright, from a solid bulb about as large as a filbert; leaves much divided and cut; petals large, roundish, bright yellow. The most showy of all the buttercups. Not common, except in Eastern New England.

IV. CALTHA, MARSH MARIGOLD.

Sepals petal-like, 5–9. Petals none. Pistils 5–10, each consisting of a one-celled ovary with a nearly sessile stigma. Fruit a many-seeded follicle (much like that of Fig. 171).

(C. PALUSTRIS), COWSLIPS, MEADOW BUTTERCUP (both unsuitable names, but in common use). Stem hollow, smooth, ascending; leaves smooth, roundish and heart-shaped, or kidney-shaped, with crenate, dentate, or nearly entire margins; the broad oval sepals bright yellow. Swamps or wet ground.

V. AQUILEGIA, COLUMBINE.

Also mistakenly called Honeysuckle.

Sepals 5, petal-like, all similar. Petals 5, all similar, each consisting of an expanded portion, prolonged backward into a hollow spur, the whole much longer than the calyx. Pistils 5, forming many-seeded pods. Perennials, with leaves twice or thrice palmately compound, the divisions in threes.

(A. Canadensis), Wild Columbine. Flowers scarlet without, yellow within, nodding; spurs rather long and hooked.

CRUCIFERÆ, MUSTARD FAMILY.

Herbs with pungent, watery juice and alternate leaves without stipules. The sepals are usually 4, often falling off early; the petals 4, arranged in the form of a cross; stamens 6, the 2 outer ones shorter than the 4 inner ones. The fruit is generally a pod, divided into two cells by a thin partition which stretches across from one to the other of the two placentæ. The flowers throughout the family are so much alike that the genera and species cannot usually be determined without examining the tolerably mature fruit.

I. DENTARIA, TOOTHWORT, PEPPER-ROOT.

Pod lance-linear, flattish. Seeds in one row, wingless; seed-stalks broad and flat. Stems naked below, 2–3-leaved above, from a thickish, more or less knotted or interrupted rootstock. Flowers rather large, in early spring.

a. (D. diphylla), Two-leaved Toothwort, Pepper-root, Crinkle-root. Rootstock long, often branched, toothed, eatable, with a flavor like that of cress or radish; stem-leaves 2, close together, each of 3 ovate-diamond-shaped and toothed or crenate leaflets; the root-leaf like the stem-leaves. Flowers white.

b. (D. laciniata), Crow's Foot. Rootstock short, necklace-like; stem-leaves 3-parted; root-leaf often absent; flowers white or rose-color.

II. CARDAMINE, BITTER CRESS.

Pods linear, much as in preceding genus. Seed-stalks slender. Smooth perennials, mostly in springs, brooks, or wet soil. Flowers smaller than in the preceding genus.

(C. RHOMBOIDEA), SPRING CRESS. Stems simple, upright or nearly so, from a tuberous base and tuber-bearing rootstock; root-leaves roundish; lower stem-leaves ovate or oval-diamond-shaped. Flowers white, rather showy.

(Variety PURPUREA.) Stems lower; flowers rose-purple; less common than the white form.

III. MATTHIOLA, STOCK, GILLYFLOWEP.

Pods nearly cylindrical, except for a prominent midrib on each valve; stigmas large and spreading; seeds winged; flowers in showy racemes of many colors ranging from white to crimson.

(M. INCANA), COMMON STOCK. Biennial or perennial, with somewhat woody stems. Cultivated from Europe in greenhouses and gardens.

IV. CAPSELLA, SHEPHERD'S PURSE.

Pods flattened at right angles to the partition, short, more or less triangular and notched at the top; ovules many in each cell.

(C. BURSA-PASTORIS), COMMON SHEPHERD'S PURSE. A well-known weed, by roadsides and in waste ground; leaves varying much in form, those from the base of the stem more or less pinnately parted or cleft, those of the stem arrow-shaped and somewhat clasping; flowers insignificant, white; raceme lengthening much as the pods mature.

V. LEPIDIUM, PEPPERGRASS.

Pods flattened as in the preceding genus, roundish, sometimes notched at the top; ovule only one in each cell, flowers insignificant, white or greenish.

(L. VIRGINICUM), PEPPERGRASS, BIRDS' PEPPER, TONGUE-GRASS. Pods notched at the top; petals small; leaves all tapering at the base, linear or lance-linear, the larger ones rather deeply and irregularly serrate.

SAXIFRAGACEÆ, SAXIFRAGE FAMILY.

Herbs or shrubs. Leaves alternate or opposite, generally without stipules. Sepals 4 or 5, more or less coherent with each other and adnate to the ovary. Petals as many as the sepals and alternate with them. Stamens as many as the petals and alternate with them, or 2–10 times as many. Ovary usually of 2 carpels, united only at the base or more or less throughout. Fruit generally a 1–2-celled capsule, sometimes a berry. Seeds many, with endosperm.

I. RIBES, CURRANT, GOOSEBERRY.

Shrubs. Leaves palmately veined and lobed, sometimes with stipules. Calyx-tube egg-shaped, adnate to the 1-celled ovary, its 5 lobes usually colored like the petals. Petals 5, small, generally inserted on the throat of the calyx-tube. Stamens 5, inserted with the petals. Styles 2. Ovary 1-celled, with 2 placentæ on its walls, becoming in fruit a pulpy (usually eatable) berry.

a. (R. ROTUNDIFOLIUM), SMOOTH WILD GOOSEBERRY. Spines few and short, prickles few or absent; leaves roundish, lobed, with the lobes crenate-dentate, often downy; peduncles slender; flowers inconspicuous; calyx-lobes reflexed; styles and stamens projecting decidedly from the calyx-tube; berries smooth.

b. (R. CYNOSBATI), PRICKLY WILD GOOSEBERRY. Spines in pairs; leaves long-peduncled, downy, cordate, cut-dentate; style single, it and the stamens not projecting from the calyx-tube; berries generally prickly, brownish-purple, pleasant-flavored.

c. (R. RUBRUM), RED CURRANT. Stems more or less reclining; leaves somewhat heart-shaped, obtusely 3–5 lobed; racemes drooping (Fig. 105); limb of the calyx wheel-shaped; berries acid, eatable, red or light amber-colored. Cultivated from Europe, also wild in the Northern U. S.

d. (R. AUREUM), GOLDEN CURRANT, FLOWERING C., MISSOURI C., CLOVE C. A much taller shrub than the common red currant; leaves 3-lobed, toothed; racemes short and loose; tube of the yellow calyx much longer than its limb; flowers very fragrant; fruit brownish-black, barely eatable.

II. SAXIFRAGA, SAXIFRAGE.

Herbs with simple or palmately cut leaves and generally cymose or panicled flowers. Sepals 5, more or less united. Petals 5, entire, inserted on the calyx-tube. Stamens 10. Capsule consisting of two (sometimes more) ovaries, united at the base, separate and diverging above.

a. (S. Virginiensis), Early Saxifrage, Mayflower. Stemless, with a cluster of spatulate, obovate, or wedge-shaped root-leaves and a scape 3–9 inches high, which bears a dense cluster of small, white flowers, becoming at length a panicled cyme; petals white, oblong, much longer than the calyx. Perennial.

b. (S. Pennsylvanica), Swamp Saxifrage. Leaves 4–8 in. long, oblong-lanceolate and tapering to the base, slightly toothed; scape 1–2 ft. high, bearing an oblong cluster of small, greenish flowers, at length diffusely panicled; petals linear-lanceolate, hardly longer than the calyx-lobes. Perennial.

III. MITELLA, MITREWORT, BISHOP'S CAP, FRINGE CUP, FAIRY CUP.

Delicate perennial herbs. Flowers small, pretty, in a simple raceme or spike. Calyx 5-cleft, adnate to the base of the ovary. Petals 5, cut-fringed, inserted on the throat of the calyx-tube. Stamens 5 or 10, not projecting from the calyx-tube. Styles 2, very short. Ovary and pod 2-beaked, globular, 1-celled.

(M. diphylla), Two-leaved Bishop's Cap. Stemless, with long-petioled, roundish cordate root-leaves, and a scape about 1 ft. high bearing two opposite, nearly sessile leaves; flowers many, racemed, white.

ROSACEÆ, ROSE FAMILY.

Herbs, shrubs, or trees, with alternate leaves, with stipules, and regular flowers. Sepals usually 5, more or less united, often alternating with bractlets. Petals 5, rarely none, inserted on the calyx (Fig. 163, I). Stamens usually indefinite, unconnected, inserted with the petals. Pistils 1–many, dis-

tinct or united. Fruit a group of akenes, a stone-fruit (Fig. 180), or a pome. Seeds 1 or few in each carpel, destitute of endosperm.

I. PRUNUS, PLUM, CHERRY, ETC.

Trees or shrubs; leaves simple, with stipules, which are often small or fall off early; calyx with a bell-shaped or urn-shaped tube and 5-lobed spreading limb, falling off after flowering; petals 5; stamens 3–5 times as numerous, or indefinite, inserted on the throat of the calyx-tube; pistil 1, long-styled, with 2 ovules, ripening into a single stone-fruit.

a. (P. AMERICANA), WILD PLUM. A tall shrub or spreading small tree, 10–15 ft. high, generally thorny, with large, obovate, taper-pointed, coarsely serrate leaves, large, white, pediceled flowers, and tough-skinned oval or roundish, reddish or yellowish fruit, with a sharp-edged or margined flattened stone.

b. (P. CERASUS), GARDEN RED CHERRY, SOUR C., MORELLO C. A spreading tree 10–30 ft. high, with ovate or obovate serrate leaves; short-pediceled, rather large flowers, appearing earlier than the leaves; and sour, red fruit. Cultivated from Europe.

c. (P. VIRGINIANA), CHOKE CHERRY. A shrub or small tree, 5–20 ft. high, with thin oval or obovate, pale, pointed, sharply serrate leaves and small white flowers in short racemes. Fruit bright red, turning at length to dark crimson, very puckery until fully ripe; stone smooth.

II. POTENTILLA, CINQUEFOIL.

Calyx flat, deeply 5-cleft, with bractlets at the base alternating with the divisions. Petals 5. Stamens indefinite. Ovaries small, on a dry receptacle, ripening into akenes. Leaves compound. Flowers single or in cymes.

a. (P. ARGUTA), UPRIGHT CINQUEFOIL. An erect, stout, hairy plant, 1–4 ft. high, with long-petioled pinnate root-leaves and few stem-leaves, each of 3–7 leaflets, the latter broadly ovate and cut-toothed or serrate, downy underneath. Flowers large, in dense terminal clusters, the petals whitish or cream-color. Perennial.

b. (P. CANADENSIS), COMMON CINQUEFOIL. Stems slender, procumbent, silky-hairy, sending out long runners, with obovate wedge-shaped leaflets appearing like 5 from the divisions of the 2 lateral ones and 1-flowered peduncles in the axils of the leaves. Perennial.

c. (P. ARGENTEA), SILVERY CINQUEFOIL. Stems prostrate or

ascending and branching, woolly, leaflets oblong wedge-shaped, with a few large, deeply cut teeth, smooth and green above, silvery beneath, with a dense coat of white wool; flowers small and somewhat clustered. Perennial.

III. ROSA, ROSE.

Calyx-tube urn-shaped, with a rather narrow mouth. Petals (in single roses) 5. Stamens many, inserted around the inside of the mouth of the calyx-tube. Ovaries many, hairy, ripening into bony akenes, enclosed in the rather fleshy and sometimes eatable calyx-tube.

a. (R. BLANDA), EARLY WILD ROSE. Stems 1–3 ft. high, usually without prickles; stipules broad; flowers generally large, corymbed or solitary; sepals after flowering closing over the mouth of the calyx-tube and persistent.

b. (R. CAROLINA), SWAMP ROSE. Stems 4–8 ft. high, with stout and generally recurved prickles; stipules long and narrow; leaflets commonly downy beneath, finely serrate; flowers several in a corymb, bright rose-color; sepals spreading and falling off after flowering.

c. (R. LUCIDA), DWARF WILD ROSE. Stems varying in height from less than a foot to 6 ft., with stout, somewhat hooked prickles; stipules rather broad; leaflets small, thickish and glossy above, coarsely toothed toward the tip; flowers corymbed, or solitary pale rose-color; sepals spreading and falling off after flowering.

LEGUMINOSÆ, PULSE FAMILY.

Herbs, shrubs, or trees. Leaves alternate, usually compound (either pinnately or palmately), with stipules, the leaflets entire. Calyx of 5 sepals, which are more or less united, often somewhat irregular. Corolla, of 5 petals, often papilionaceous (Fig. 119), or somewhat regular. Stamens diadelphous (Fig. 130), monadelphous, or distinct. Ovary simple, superior. Fruit usually a 1-celled pod (Fig. 162). Seeds one or several, without endosperm.

I. TRIFOLIUM, CLOVER.

Herbs, mostly with palmately compound leaves; flowers in heads, short spikes, or umbels which resemble heads; calyx with 5 bristle-like teeth; petals with claws, which are more

or less joined together below,—the corolla withering over the fruit; stamens 10, diadelphous, the tube of joined filaments united below with the corolla; pod generally not opening, short and almost covered by the calyx.

a. (T. PRATENSE), RED CLOVER. Stems ascending, somewhat hairy; leaflets oval or obovate, sometimes notched at the tip, usually with a pale spot on the upper surface; heads sessile, dense, with many rose-red, sweet-scented flowers. Perennial. Cultivated from Europe, also becoming wild.

b. (T. REPENS), WHITE CLOVER. Stems smooth, creeping and rooting at the joints; leaves small, long-petioled, with inversely heart-shaped leaflets; heads globular, loose, long-peduncled, with whitish flowers, the pedicels reflexed in fruit. Perennial.

II. ROBINIA, LOCUST.

Trees or shrubs. Leaves pinnately compound (Fig. 76), often furnished with persistent spiny stipules (Fig. 188), the leaflets with stipels. Flowers showy and fragrant, in axillary racemes. Calyx 5-cleft. Corolla decidedly papilionaceous, with a large standard. Stamens diadelphous. Style bearded inside. Pod rather long, much flattened, containing many hard, shining, flattish seeds.

(R. PSEUDACACIA), COMMON LOCUST. A tree 30–80 ft. high, with rather coarse-grained wood, very durable in the ground for posts, &c., and spiny branches; racemes of large fragrant white flowers, rather long and loose.

III. WISTARIA.

High-climbing shrubs, with odd-pinnate leaves of many leaflets and large, showy, lilac-purple flowers in long, drooping racemes. Calyx two-lipped, the upper lip merely notched, the lower with 3 nearly equal teeth. Standard large and roundish. Pod knobbed, containing many kidney-shaped seeds.

a. (W. FRUTESCENS), AMERICAN WISTARIA. Racemes rather dense; wing petals, each with one short and one long appendage at the base; ovary smooth.

b. (W. SINENSIS), CHINESE WISTARIA. Racemes longer and more drooping than in the American species; appendage of the wing petals occurring only on one side; ovary downy. Cultivated from China.

IV. LATHYRUS, SWEET PEA, WILD PEA.

Herbs, climbing by means of tendrils which terminate the petiole (as in Fig. 159). Leaves of 1 to several pairs of leaflets. Peduncles axillary, bearing 1 to several flowers, which are often very showy. Calyx bell-shaped. Stamens diadelphous (Fig. 161, I). Corolla decidedly papilionaceous (Fig. 159). Style flat, bent at a right angle, hairy along the inner side. Pod several-seeded (Fig. 161, II, III).

a. (L. ODORATUS), SWEET PEA. Stem roughish-hairy, it and the petioles winged, leaflets only one pair, oval or oblong (Fig. 111); flowers large, 2 or 3 on the long peduncles, sweet-scented, white, rose-color, purple, or variegated. Annual, cultivated from Europe.

b. (L. MARITIMUS), BEACH PEA. Stem stout, 1–2 ft. high; stipules broadly ovate and heart or halberd shaped, nearly as large as the 6–12 leaflets, of which the lower pair is the largest; tendrils much as in the sweet pea; flowers large, blue or purple. A seashore perennial herb.

c. (L. PALUSTRIS.) Stem frequently winged, slender, and climbing by delicate tendrils at the ends of the leaves; stipules narrow and pointed; leaflets 4–8, narrowly oblong to linear, acute; peduncles bearing 2–6 pretty large, drooping, blue, purple, and white flowers.

EUPHORBIACEÆ, SPURGE FAMILY.

Plants usually with a milky, more or less acrid and sometimes poisonous juice and mostly apetalous, monœcious or diœcious flowers; the ovary usually 3-celled, with one or two ovules in each cell; stigmas as many as the cells or twice as many; fruit a 3-lobed capsule; seeds containing fleshy or oily endosperm (Fig. 1). Most of the family are natives of hot regions, many of them of peculiar aspect from their adaptation to life in dry climates (Fig. 89). The family is too difficult for the beginner in botany to determine many of its genera and species with certainty.

MALVACEÆ, MALLOW FAMILY.

Herbs or shrubs with simple, alternate, palmately-veined leaves, with stipules. Flowers regular, with 5 sepals, often surrounded by an involucre at the base, 5 petals, numerous

monadelphous stamens (Fig. 129), and several more or less distinct pistils. Fruit a several-celled capsule or a collection of 1-seeded carpels.

I. MALVA, MALLOW.

Calyx 5-cleft, with a small 3-leaved involucre. Petals obcordate or truncate. Styles many, slender, with stigmas running down the sides (Fig. 154). Carpels many, 1-seeded, arranged in a circle and separating from each other, but not opening when ripe.

a. (M. ROTUNDIFOLIA), COMMON MALLOW, CHEESES (from appearance of the unripe fruit). A common weed, with nearly prostrate stems; long-petioled, round-kidney-shaped leaves, with crenate margins; and small whitish flowers on long peduncles. Biennial or perennial.

b. (M. SYLVESTRIS), HIGH MALLOW. Stem erect, 2–3 ft. high, with 5–7-lobed leaves and purplish flowers, larger than those of the preceding species. Biennial or perennial.

II. ABUTILON, INDIAN MALLOW.

Calyx 5-cleft, the tube often angled. Styles 5–20, with knobbed stigmas. Carpels as many as the styles, arranged in a circle, each 1-celled, 3–6-seeded, and opening when ripe by 2 valves.

(A. STRIATUM), TASSEL TREE, FLOWERING MAPLE. A shrub 5–10 ft. high, with maple-like leaves and showy solitary flowers nodding on slender peduncles; corolla not opening widely, orange, striped with reddish-brown veins; column of stamens projecting beyond the corolla like a tassel. Cultivated in hot-houses, from Brazil.

VIOLACEÆ, VIOLET FAMILY.

Herbs with simple, alternate leaves, with stipules (Fig. 72). Calyx of 5 persistent sepals. Corolla — somewhat irregular, one petal with a spur — of 5 petals. Stamens 5, short, the filaments often cohering around the pistil. Style generally club-shaped, with a one-sided stigma, with an opening leading to its interior. Pod 1-celled, splitting into 3 valves, each bearing a placenta. The seeds are often dispersed by the splitting of the elastic valves.

VIOLA, VIOLET.

Sepals ear-like at the base. Petals somewhat irregular, some of them bearded within, thus affording a foothold for bees, the lowest one with a spur at the base (Fig. 147). Stamens not cohering very much, the two lowermost with spurs which reach down into the spur of the lowest petal. Many species bear inconspicuous apetalous flowers later than the showy ordinary ones and produce most of their seed from these closed, self-fertilized flowers. (See Miss Newell's *Botany Reader*, Part II, Chapter V.)

* *Stemless perennials.*

a. (V. PEDATA), BIRD-FOOT VIOLET, HORSE-SHOE V., SAND V. Leaves all palmately 5–9-parted into linear or linear-lanceolate divisions. Flowers showy, about 1 in. broad, pale violet to whitish; petals not bearded. Rootstock stout, upright, not scaly.

b. (V. PALMATA), COMMON BLUE VIOLET. Earlier leaves roundish heart-shaped or kidney-form and crenate, with the sides rolled in at the base when young. The later ones variously cleft or parted. Flowers dark or light blue, sometimes whitish; the lateral petals bearded. Rootstock stout and scaly.

(Variety CUCULLATA), COMMON BLUE VIOLET, HOOD-LEAF V. Later leaves remaining nearly crenate, like the earlier ones, in rich soil becoming very luxuriant.

c. (V. SAGITTATA), ARROW-LEAVED VIOLET, SPADE-LEAF V. Leaves very variable, ranging in shape from oblong-heart-shaped to triangular-halberd-shaped, very often with an arrow-shaped base, the earlier ones on short, margined petioles, the later frequently long-petioled. Flowers rather large, otherwise much as in the preceding species.

d. (V. BLANDA), SWEET WHITE VIOLET. Leaves roundish heart-shaped or kidney-shaped. Flowers rather small, whitish, sweet-scented, generally beardless, with the lowermost petal exquisitely veined with dark purple lines. Rootstock long, slender, and creeping. In damp or marshy ground.

** *Leafy-stemmed perennials.*

e. (V. PUBESCENS), DOWNY YELLOW VIOLET. Soft, downy, 6–12 in. high; leaves broadly heart-shaped, toothed, with large stipules. Flowers yellow, with a short spur.

f. (V. Canadensis), Canada Violet. Stems very leafy, smooth, 1 ft. or more high. Leaves heart-shaped, taper-pointed, serrate. Flowers large and handsome; petals white, or nearly so, inside, — the upper ones usually violet-tinged beneath, lateral petals bearded.

*** *Leafy-stemmed, from an annual, biennial, or occasionally short-lived perennial root; stipules about as large as the leaves. Fig. 72.*

g. (V. tricolor), Pansy, Heart's-ease. Stem branching, angular, hardly erect; leaves variable, more or less ovate, crenate. Flowers large (often more than 1 in. across), flattish, short-spurred, exceedingly variable in color. Cultivated from Europe.

(Variety arvensis), Johnny-jump-up, Lady's Delight. A small-flowered variety, running wild in gardens and sometimes appearing like a native plant.

UMBELLIFERÆ, PARSLEY FAMILY.

Herbs, usually with hollow, grooved stems and small flowers, generally in umbels. Calyx-tube adnate to the ovary; limb of the calyx either wanting or present only as a 5-toothed rim or margin around the top of the ovary. Petals 5 and stamens 5, inserted on the disk which is borne by the ovary. Ovary 2-celled and 2-ovuled, ripening into 2 akene-like carpels, which split away from each other. Each carpel bears 5 longitudinal ribs, in the furrows between which secondary ribs frequently occur. On a cross-section of the fruit oil-tubes are seen, traversing the interspaces between the ribs, and pretty near the surface of the fruit. The seeds contain a small embryo, enclosed in considerable endosperm. (The family is a difficult one, since the flowers are so much alike that the species are distinguished from each other mainly by rather minute characteristics of the fruit.)

I. HERACLEUM, COW PARSNIP.

Calyx with 5 small teeth. Fruit tipped with a thick conical enlargement of the style, with three blunt ribs on the outer surface of each carpel and a large oil-tube in each interval

between the ribs. Seeds flat. A stout perennial with the very large leaves compound in threes. Umbels large, compound, with the involucels many-leaved. Petals white, inversely heart-shaped, the outer ones usually 2-cleft and larger.

(H. LANATUM.) Stem grooved and woolly, 4–8 ft. high; leaflets petioled, broad, deeply and irregularly toothed.

II. CARUM, CARAWAY, PARSLEY.

Calyx-teeth minute. Fruit smooth, oblong or ovate, with thread-like ribs; oil-tube single in the intervals between the ribs; base of the styles thickened into a conical mass. Herbs with slender, smooth stems, pinnately compound smooth leaves, compound umbels, and white or yellowish flowers.

(C. CARUI), CARAWAY. Leaves large, with the leaflets cut into numerous thread-like divisions; flowers white; fruit aromatic, used somewhat in this country and more in N. Europe for flavoring cookies, bread, etc. Perennial.

III. OSMORRHIZA, SWEET CICELY.

Calyx-teeth wanting. Fruit linear or nearly so, tapered away at the base, with 5 equal bristly ribs, without oil-tubes. Perennials, springing from stout aromatic roots, with leaves compound in threes and white flowers in compound umbels.

a. (O. BREVISTYLIS), HAIRY SWEET CICELY. Rather stout and hairy. Style and its enlarged base somewhat conical; root nauseous.

b. (O. LONGISTYLIS), SMOOTH-LEAVED SWEET CICELY. Smooth or nearly so. Style rather thread-like; root of a pleasant aromatic flavor (as is also the fruit).

Caution. So many plants of this family have actively poisonous roots and foliage that it is unsafe for any one but a botanist, who can distinguish the poisonous species from the harmless ones, to taste them.

Division III.

GAMOPETALOUS PLANTS. FLOWERS WITH THE PETALS MORE OR LESS UNITED TO EACH OTHER. (IN A FEW THE PETALS ARE SEPARATE.)

ERICACEÆ, HEATH FAMILY.

Usually shrubs or slightly shrubby plants. Leaves simple, generally alternate. Corolla commonly regular, 4–5-cleft, sometimes polypetalous. Stamens hypogynous, distinct, as many or twice as many as the petals, the anthers mostly opening by a hole at the end (Fig. 138, III). Ovary usually with as many cells as there are corolla-lobes; style 1. Seeds small, with albumen. The family is divided into several sub-families, of which two are here described.

I. WHORTLEBERRY SUB-FAMILY.

Shrubs. Calyx-tube adnate to the ovary, on which the gamopetalous corolla and the stamens are borne. Fruit a true berry, or resembling one.

I. GAYLUSSACIA, HUCKLEBERRY.

Calyx 5-toothed. Corolla urn-shaped or bell-shaped, 5-cleft or 5-toothed. Stamens 10, the anthers opening by holes in the blunt or tapered ends of the cells. Ovary 10-celled, each cell containing a single ovule, the whole forming a berry-like, 10-seeded stone-fruit. Flowers small, white or pinkish, in lateral bracted racemes. Leaves and little twigs generally dotted over with resinous particles.

a. (G. RESINOSA), COMMON HUCKLEBERRY. A small, stiff-branched shrub, 1–3 ft. high, with oval leaves, and short, one-sided racemes of somewhat cylindrical flowers; fruit black with no bloom, sweet, commonly gathered for sale.

b. (G. FRONDOSA), DANGLEBERRY. A slender-branched shrub, 3 ft. or more in height, with oblong-obovate leaves, very pale beneath,

slender racemes, with moderately long pedicels of short, somewhat egg-shaped flowers; fruit bluish black with a bloom, sweet, commonly gathered for sale.

II. VACCINIUM, BLUEBERRY, CRANBERRY.

Calyx 5-toothed. Corolla urn-shaped, bell-shaped, or cylindrical, the limb 4 or 5-cleft, reflexed. Stamens 8 or 10, each of the anther-cells prolonged into a tube opening at the top. Ovary several to many-ovuled, ripening into a commonly many-seeded berry. The fruit of all the species here described excepting *V. stamineum*, the deerberry, is much valued.

a. (V. PENNSYLVANICUM), COMMON DWARF BLUEBERRY. A low, delicate shrub, 6–15 in. high, with green branches, shining oblong leaves, bristly-serrulate and acute at both ends; flowers in short, close racemes, oblong or nearly so, with the anthers enclosed in the corolla-tube; berries 10-celled, many-seeded, somewhat flattened, usually with much bloom, sweet, the earliest blueberries in the market.

b. (V. VACILLANS), LOW BLUEBERRY. A low bushy shrub, 1–3 ft. high; leaves obovate to oval, acute, entire or nearly so, dull, pale green, smooth beneath; racemes dense, appearing before the leaves are fully grown; berries 10-celled, not large, sweet, bluish black.

c. (V. CORYMBOSUM), SWAMP BLUEBERRY, HIGH BLUEBERRY. A tall, rather erect shrub, 5–10 ft. high; leaves from oval to broadly lanceolate, in some varieties smooth, in others downy; berries 10-celled, generally with a bloom, more acid and frequently larger than in the two preceding species, ripening later. Occurs in low wet woods or in swamps; very variable.

d. (V. STAMINEUM), DEERBERRY, SQUAW HUCKLEBERRY. A somewhat downy shrub, 2–3 ft. high; leaves ovate, oval or oval-lanceolate, acute, dull and pale, smooth beneath; pedicels solitary in the axils; corolla spreading, bell-shaped, greenish or whitish; anthers 10, projecting from the corolla-tube; fruit greenish white, 10-celled, few-seeded, barely eatable.

e. (V. MACROCARPON), CRANBERRY. A delicate creeping plant, with barely woody stems 1–3 feet long; leaves evergreen, oblong, obtuse, white beneath, with the edges somewhat rolled under; pedicels slender, axillary, 1-flowered; corolla pale rose-color, parted into 4 linear-lanceolate, reflexed divisions; stamens 8; berries 4-celled, many-seeded, somewhat spherical or ellipsoidal, large, in some localities reddish purple, in others deep purple, very acid. Grows usually in peat-bogs or in meadows which are sometimes overflowed.

II. TRUE HEATH SUB-FAMILY.

Shrubs or small trees. Calyx free from the ovary. Corolla hypogynous, usually gamopetalous.

EPIGÆA, GROUND LAUREL, TRAILING ARBUTUS.

Calyx large, 5-parted, with 3 bracts at the base, its divisions ovate-lanceolate and almost distinct; corolla salver-shaped, with its tube hairy within. Stamens 10, the anthers opening lengthwise. Style slender, capsule 5-celled, many-seeded.

(E. REPENS), MAYFLOWER. A prostrate, creeping, barely shrubby plant, with large roundish heart-shaped, evergreen, hairy leaves and very fragrant pink or nearly white flowers in early spring.

PRIMULACEÆ, PRIMROSE FAMILY.

Herbs with simple leaves, often most or all of them radical. Flowers perfect and regular, generally gamopetalous. Stamens commonly 5, inserted on the corolla, opposite its lobes. Pistil consisting of a single stigma and style and a (generally free) one-celled ovary, with a free central placenta (Fig. 132, *c*).

I. DODECATHEON, SHOOTING STAR.

Calyx deeply 5-cleft, with reflexed, lanceolate divisions. Tube of the corolla very short, the divisions of the 5-parted limb strongly reflexed. Filaments short, somewhat united at the base; anthers long, acute, and combining to form a conspicuous cone. A smooth perennial herb, with a cluster of oblong or spatulate root-leaves, fibrous roots, and an unbranched scape, leafless except for an involucre of small bracts at the summit, with a large umbel of showy nodding flowers. Corolla varying from rose-color to white.

(D. MEADIA), SHOOTING STAR, INDIAN CHIEF. Native in most of the Middle and Southern States. Often cultivated.

II. PRIMULA, PRIMROSE.

Calyx tubular, decidedly angled, 5-cleft. Corolla more or less salver-shaped, with the tube widened above the insertion of the stamens (Fig. 157); the 5 lobes of the limb often notched or cleft. Stamens 5, not protruding outside the corolla-tube. Capsule egg-shaped, splitting at the top into 5 valves, each of which may divide in halves. Low perennial herbs, with much veined root-leaves; scapes each bearing an umbel of flowers, which are often showy.

(P. GRANDIFLORA), TRUE PRIMROSE. Leaves spatulate or obovate-oblong. Flowers rising on separate slender pedicels from the leaf-axils, corolla originally pale yellow, but varying to white, red, and many intermediate shades, with a broad, flat limb. Cultivated from Europe.

III. LYSIMACHIA, LOOSESTRIFE.

Calyx 5–6-parted. Corolla wheel-shaped, with its divisions commonly nearly separate. Stamens generally somewhat monadelphous at the base. Perennials with opposite or whorled entire leaves, which are often dotted.

a. (L. QUADRIFOLIA), FOUR-LEAVED LOOSESTRIFE. Stem erect and simple, 1–2 ft. high, hairy; leaves whorled, most frequently in fours, broadly lanceolate; flowers small, axillary, and solitary, on long and slender peduncles.

b. (L. STRICTA), BULB-BEARING LOOSESTRIFE. Stems 1–2 ft. high, finally branching, frequently producing bulblets in the leaf-axils after flowering; leaves abundant, generally opposite, narrowly lanceolate; the small flowers pedicelled, in a long terminal raceme.

BORRAGINACEÆ, BORAGE FAMILY.

Mostly herbs, with stems and foliage roughened with stiff hairs, with leaves alternate and entire, and symmetrical flowers, generally in a coiled inflorescence. Calyx 5-parted. Corolla generally 5-lobed and regular. Stamens 5, inserted on the corolla-tube. Style one; ovary commonly 4-lobed, ripening into 4 1-seeded nutlets. Seeds without endosperm.

I. MERTENSIA, LUNGWORT.

Calyx short, deeply 5-cleft or 5-parted. Corolla somewhat trumpet-shaped or funnel-shaped, often with 5 small folds or ridges in the throat, between the points of insertion of the stamens. Style long and slender. Nutlets smooth, or at length becoming wrinkled. Leaves generally pale, smooth, and entire. Perennial herbs.

(M. VIRGINICA), LUNGWORT, BLUE BELLS. Smooth, nearly erect, 1–1½ ft. high; root-leaves large, obovate, or nearly so, and petioled, stem-leaves smaller, sessile; flowers clustered, corolla nearly trumpet-shaped, varying with age from lilac to blue (or occasionally white), stamens with slender filaments projecting beyond the corolla-tube.

II. LITHOSPERMUM, GROMWELL, PUCCOON.

Corolla funnel-shaped or salver-shaped, with or without folds or appendages at the mouth of the tube; the limb 5-cleft, its divisions rounded. Stamens included in the corolla-tube, the anthers nearly sessile. Nutlets either smooth or wrinkled, generally very hard and bony. Herbs, with stout, usually reddish roots; flowers appearing axillary and solitary or else in leafy-bracted spikes.

a. (L. ARVENSE), CORN GROMWELL. A rough weed, about 1 ft. high, with narrowly lanceolate leaves and inconspicuous whitish flowers in the upper leaf-axils; corolla hardly extending beyond the calyx, without appendages in the throat; nutlets rough or wrinkled and dull.

b. (L. HIRTUM), HAIRY PUCCOON. Rough-hairy, 1–2 ft. high; corolla deep orange-yellow, with appendages in the throat and clad with wool within at the bottom; flowers handsome, peduncled, in a crowded cluster. Perennial.

c. (L. CANESCENS), PUCCOON, INDIAN PAINT. Clothed with soft hairs 8–12 in. high; flowers axillary and sessile; corolla appendaged, not woolly within, showy, orange-yellow.

LABIATÆ, MINT FAMILY.

Mostly herbs, with square stems and opposite, more or less aromatic leaves, without stipules. Flowers generally in

cyme-like axillary clusters, which are often grouped into terminal spikes or racemes. Calyx tubular, usually 2-lipped, persistent. Corolla usually 2-lipped. Stamens 4 (2 long and 2 short) or only 2. Ovary free, with 4 deep lobes, which surround the base of the style. Fruit consisting of 4 nutlets, ripening inside the base of the calyx.

I. **NEPETA**, CATNIP, GROUND IVY.

Calyx tubular, 5-toothed, corolla-tube narrow below, widened in the throat; corolla 2-lipped, the upper lip notched, the lower 3-lobed, with the middle lobe largest. Stamens 4, rising inside the upper lip. Perennial herbs.

(N. GLECHOMA), GROUND IVY, GILL-OVER-THE-GROUND, CREEPING CHARLEY, CROW-VICTUALS, ROBIN-RUNAWAY. Creeping in damp places; leaves roundish kidney-shaped and crenate; corolla bluish purple, three times as long as the calyx.

II. **BRUNELLA**, SELF-HEAL.

Calyx tubular-bell-shaped, somewhat 10-ribbed, upper lip broad 3-toothed, the teeth short, lower lip with 2 longer teeth. Upper lip of the corolla upright, arched, and entire, the lower spreading, reflexed, fringed, and 3-cleft. Stamens 4, reaching up under the upper lip, with the tips of the filaments 2-toothed, only one tooth anther-bearing. Perennials, with stems simple or nearly so, and sessile, 3-flowered flower-clusters in the axils of kidney-shaped bracts, the whole forming a spike or head.

(B. VULGARIS), SELF-HEAL, HEAL-ALL, CARPENTER-WEED. Leaves with petioles, ovate-oblong, either entire or toothed, often somewhat hairy; corolla usually blue or bluish, somewhat longer than the brown-purple calyx.

III. **LAMIUM**, DEAD NETTLE.

Calyx tubular-bell-shaped, 5-veined, with 5 awl-pointed teeth of nearly equal length. Corolla with dilated throat, upper lip arched, middle lobe of the lower lip notched, the

lateral lobes small, close to the throat of the corolla. Stamens 4, rising beneath the upper lip. Low spreading herbs.

(L. AMPLEXICAULE), HEN-BIT. An annual or biennial weed with small purple flowers. Leaves roundish, deeply crenate, the lower ones petioled, the upper sessile and clasping.

SOLANACEÆ, NIGHTSHADE FAMILY.

Usually herbs, mostly tropical, with colorless juice, which is sometimes acrid, nauseous, or poisonous, and alternate leaves. Flowers regular, on bractless pedicels; calyx 5-parted; corolla more or less 5-parted, lobed, or angled; stamens 5; pistil consisting of a single style and stigma and a compound ovary, ripening into a (generally 2-celled) capsule or berry. Seeds with endosperm.

I. SOLANUM, NIGHTSHADE, POTATO.

Calyx generally 5-parted or 5-cleft. Corolla generally 5-parted, cleft, or angled and wheel-shaped or nearly so (Fig. 124). Anthers nearly sessile, enclosing the style. Berries commonly 2-celled.

(S. DULCAMARA), BITTERSWEET. Stems rather shrubby, long, and climbing; leaves heart-shaped, or some of them with irregular lobes, or ear-like leaflets at the base; the blue or purple flowers somewhat cymose; berries showy, of many shades of orange and red in the same cluster, according to their maturity. Perennial.

II. PETUNIA.

Divisions of the calyx oblong-spatulate. Corolla showy, spreading funnel-shaped, not perfectly regular. Stamens 5, somewhat unequal in length, inserted in the middle of the corolla-tube and not projecting beyond it. Capsule 2-celled, containing many very small seeds. Leaves alternate and entire.

a. (P. VIOLACEA), COMMON PETUNIA. Stems rather weak and reclining; leaves covered with clammy down; corolla varying from purplish to bright red, often variegated, with a broad, inflated tube, which is hardly twice as long as the calyx. Cultivated annual from South America.

b. (P. NYCTAGINIFLORA), WHITE PETUNIA. Tube of corolla long and slender; flowers white; leaves somewhat petioled. Cultivated from South America. This and the preceding species much mixed by hybridization.

SCROPHULARIACEÆ, FIGWORT FAMILY.

Mostly herbs with irregular flowers. Calyx free from the ovary and persistent. Corolla 2-lipped or otherwise more or less irregular. Stamens usually 2 long and 2 short or only 2 in all, inserted on the corolla-tube, often 1 or 3 of them imperfectly developed. Pistil consisting of a 2-celled and usually many-ovuled ovary, with a single style and an entire or 2-lobed stigma.

I. VERONICA, SPEEDWELL.

Calyx usually 4-parted. Corolla rather wheel-shaped, with its limb generally somewhat irregularly 4-parted. Stamens 2, inserted on the corolla-tube and projecting beyond it. Style 1; stigma 1. Capsule flattened, obtuse, notched or inversely heart-shaped at the summit, 2-celled, generally few-seeded. Mostly herbs with opposite or whorled leaves.

a. (V. OFFICINALIS), COMMON SPEEDWELL, GYPSY WEED. Roughish downy, with the prostrate stems spreading and rooting; leaves wedge-oblong or nearly so, obtuse, serrate, somewhat petioled; racemes dense, of many pale bluish flowers; capsule rather large, inversely heart-shaped and somewhat triangular. Perennial.

b. (V. SERPYLLIFOLIA), THYME-LEAVED SPEEDWELL. Smooth or nearly so; branching and creeping below, but with nearly simple ascending shoots, 2–4 in. high; leaves slightly crenate, the lowest ones petioled and roundish, those farther up ovate or oblong, the uppermost ones mere bracts; raceme loosely flowered; corolla nearly white or pale blue, beautifully striped with darker lines; capsule inversely heart-shaped, its width greater than its length. Perennial.

c. (V. PEREGRINA), PURSLANE SPEEDWELL. A homely, rather fleshy, somewhat erect-branched weed, 4–9 in. high; the lowest leaves petioled, oblong, somewhat toothed, those above them sessile, the uppermost ones broadly linear and entire; flowers solitary, inconspicuous, whitish, barely pediceled, appearing to spring from the axils of the small floral leaves; corolla shorter than the calyx; capsule roundish, barely notched, many-seeded. Annual.

II. **CASTILLEIA,** PAINTED CUP.

Flowers yellow or purplish in terminal leafy spikes. Calyx tubular, flattened, 2–4-cleft. Corolla-tube included within the calyx ; upper lip of the corolla very long, linear, arched, and enclosing the stamens, 2 of which are long and 2 short. Ovary many-ovuled. Herbs parasitic on the roots of other plants, with alternate leaves ; the floral ones usually colored at the tip and more showy than the flowers.

(C. COCCINEA), SCARLET PAINTED CUP, PAINT-BRUSH, INDIAN PINK, PRAIRIE FIRE, WICKAKEE. A hairy, simple-stemmed herb, with clustered obovate or oblong root-leaves and cut stem-leaves ; floral leaves 3–5 cleft and bright scarlet (occasionally yellow) toward the tips, as though dipped in a scarlet dye ; calyx nearly as long as the pale yellow corolla, 2-cleft. The spikes are often very broad, making this one of the most conspicuous of our native flowers. Annual or biennial.

III. **PEDICULARIS,** LOUSEWORT.

Corolla markedly 2-lipped ; the upper lip much flattened laterally and arched, the lower lip spreading, 3-lobed. Stamens 4, beneath the upper lip. Capsule 2-celled, tipped with abrupt point, several-seeded. Perennial herbs, with the lower leaves pinnately cut and the floral ones reduced to bracts ; flowers spiked.

(P. CANADENSIS), COMMON LOUSEWORT. Hairy, with clustered simple stems, 1 ft. high or less ; the leaves petioled, the lowermost ones pinnately parted, the others somewhat pinnately cut ; spike short, closely flowered and leafy-bracted ; calyx split down the front ; corolla greenish yellow and purplish, with its upper lip hood-like, curved under, and with 2 awl-like teeth near the end ; capsule flat, broadly sword-shaped.

RUBIACEÆ, MADDER FAMILY.

Plants with opposite and stipulate or whorled entire leaves. Calyx-tube adnate to the ovary ; limb of the calyx 4–5-cleft. Corolla regular, inserted on the calyx-tube, as many-lobed as the calyx. Stamens equaling in number the divisions of the

corolla, alternating with them, and inserted upon the corolla-tube. Ovary usually 2-celled. Style single or somewhat divided. Flowers always perfect, frequently dimorphous (as in Houstonia, Mitchella, and Bouvardia). Mainly a tropical family, including many important trees.

I. HOUSTONIA, BLUETS.

Calyx 4-lobed, persistent. Corolla salver-shaped or funnel-shaped. Stamens 4, inserted on the corolla. Style 1; stigmas 2. Ovary 2-celled. Capsule often 2-lobed, its upper portion projecting from the calyx-tube and unconnected with it. Seeds few-several in each cell. Flowers dimorphous.

(H. CŒRULEA), BLUETS, INNOCENCE, QUAKER LADIES, EYE-BRIGHT. A delicate, smooth herb, with slender, erect, forking stems 3–5 in. high, from thread-like rootstocks; leaves ovate-spatulate or oblong-spatulate, about $\frac{1}{4}$ in. long; peduncle erect and thread-like, 1 or 2-flowered; corolla sky-blue, varying to lavender or whitish, with a yellow eye; tube long and narrow; pod broad and somewhat 2-lobed. Perennial.

II. MITCHELLA, PARTRIDGE BERRY.

Flowers growing in pairs, joined by their ovaries. Calyx 4-toothed. Corolla funnel-shaped, with the lobes bearded within. Stamens 4, short. Style 1, stigmas 4, slender. Fruit double, composed of the united ovaries, berry-like, but really a stone-fruit containing 8 seed-like bony nutlets. A pretty trailing evergreen herb, with roundish-ovate, petioled leaves, fragrant white or pinkish dimorphous flowers, and tasteless scarlet berries which cling to the plant through the winter.

(M. REPENS), PARTRIDGE BERRY, SQUAW VINE, TWO-EYE BERRY. Common in dry woods, especially under evergreen coniferous trees.

III. BOUVARDIA.

Calyx 4-lobed, the divisions slender. Corolla with a long and narrow or rather trumpet-shaped tube and spreading 4-lobed limb. Anthers 4, inserted in the throat of the

corolla, almost sessile. Stigmas 2, flat. Capsule globular, 2-celled, many-seeded. Flowers dimorphous.

a. (B. TRIPHYLLA), THREE-LEAVED BOUVARDIA. Somewhat shrubby; leaves nearly smooth, ovate or oblong-ovate, the lower ones in threes, the upper ones sometimes in pairs; corolla scarlet and slightly downy outside.

b. (B. LEIANTHA), DOWNY-LEAVED BOUVARDIA. Leaves rather downy; corolla deep scarlet, smooth outside.

Both species cultivated from Mexico, in greenhouses.

CAPRIFOLIACEÆ, HONEYSUCKLE FAMILY.

Mostly shrubs. Leaves opposite, without true stipules. Flowers often irregular. Calyx-tube adnate to the ovary. Corolla tubular or wheel-shaped. Stamens usually as many as the corolla-lobes and inserted on the corolla-tube. Fruit a berry, stone-fruit, or capsule. Seeds with endosperm.

I. SAMBUCUS, ELDER.

Calyx limb minute or wanting. Corolla with a small, rather urn-shaped tube and a flattish, spreading, 5-cleft limb. Stamens 5. Stigmas 3, sessile. Fruit a globular, pulpy stone-fruit, 3-seeded, appearing like a berry. Shrubs with odd-pinnate leaves and very many small white flowers in compound cymes.

a. (S. CANADENSIS), COMMON ELDER. Stems 5–10 ft. high, with a thin cylinder of wood surrounding abundant white pith. Leaflets 5–11, oblong, taper-pointed, smooth; cymes flat and often very large; fruit purplish black, insipid or almost nauseous, but somewhat used in cookery.

b. (S. RACEMOSA), RED-BERRIED ELDER. More woody, with brown pith; leaflets fewer, downy beneath, especially when young; cymes panicled and somewhat pyramidal; fruit scarlet.

II. VIBURNUM, ARROWWOOD, BLACK HAW.

Calyx small, 5-toothed. Corolla wheel-shaped, with a 5-lobed limb. Stamens 5. Stigmas 1–3. Fruit a pulpy, 1-seeded stone-fruit, often eatable, usually with a flattish stone.

* *Flowers round the margin of the cyme without stamens or pistils, large and showy.*

a. (V. LANTANOIDES), HOBBLE-BUSH, WITCH-HOBBLE. A shrub about 5 ft. high, with the branches reclining and often rooting and forming loops (whence the popular names). Leaves very large, roundish, abruptly taper-pointed, serrate, with a rusty down on the petioles and veinlets; cymes very broad and showy; fruit red, not eatable.

b. (V. OPULUS), CRANBERRY TREE, HIGH BUSH CRANBERRY. A handsome, upright shrub; leaves 3–5-ribbed and 3-lobed; fruit bright red, juicy, very acid, and used as a substitute for cranberries.

** *Flowers all small and perfect.*

c. (V. DENTATUM), ARROWWOOD. (Name given from the fact that the straight stems were used by the Indians for arrows.) A shrub 5–10 ft. high; leaves pale, roundish ovate, very sharply toothed and strongly veined, often with tufts of hairs in the axils of the veins; fruit bright blue.

d. (V. PRUNIFOLIUM), BLACK HAW. Leaves smooth, shining above, oval or obovate, serrate with fine, sharp teeth, obtuse or nearly so, petioles hardly margined; fruit oval, somewhat flattened, sweet and insipid, but eatable.

III. **LONICERA**, HONEYSUCKLE.

Calyx 5-toothed, with a short tube. Corolla tubular, funnel-shaped or broader, 5-lobed, with the lobes somewhat unequal. Stamens 5, projecting from the corolla-tube. Ovary 2–3-celled, ripening into a several-seeded berry. Shrubs, often twining, with entire leaves, and usually showy flowers.

* *Stems twining.*

a. (L. SEMPERVIRENS), TRUMPET HONEYSUCKLE. Leaves oblong, pale beneath, rather thick, evergreen (at the South); flowers not fragrant, whorled in short spikes; corolla-tube long and narrow, limb 5-lobed, nearly regular, usually scarlet outside and yellowish inside; berries red. A native shrub, often cultivated, climbing about 15 ft. high.

b. (L. CAPRIFOLIUM), EUROPEAN HONEYSUCKLE. Leaves smooth and deciduous, several of the upper pairs united at their bases to form a flattish disk or somewhat cup-shaped leaf; flowers in

a single terminal whorl, very sweet-scented; corolla whitish, red, or yellow, two-lipped, with the lips recurved. A moderately high-climbing shrub, cultivated from Europe.

* * *More or less upright bushes, not climbing.*

c. (L. TATARICA), TARTARIAN HONEYSUCKLE. A branching shrub, 5–8 ft. high, with oval or ovate, heart-shaped, shining leaves and many showy rose-colored flowers; fruit consisting of two red berries; somewhat united below at maturity.

d. (L. CILIATA), EARLY FLY HONEYSUCKLE. A straggling bush, 3–5 ft. high, with ovate or oval, slightly heart-shaped thin leaves, at first downy beneath; flowers straw-yellow, on short, slender peduncles; corolla-lobes nearly equal, tube pouched at the base; fruit, two separate red berries.

IV. DIERVILLA, BUSH HONEYSUCKLE.

Calyx with a limb of 5 linear divisions. Corolla funnel-shaped, almost regularly 5-lobed. Stamens 5. Ovary slender, 2-celled, ripening into a 2-valved, many-seeded pod. Low upright shrubs with taper-pointed serrate leaves and flowers in loose terminal or axillary clusters or cymes.

(D. TRIFIDA), COMMON BUSH HONEYSUCKLE. Bushy, 1–4 ft. high, with ovate or oblong-ovate petioled leaves, 1–3-flowered peduncles, and pods tapering to a slender point.

COMPOSITÆ, COMPOSITE FAMILY.

Flowers in a dense head, on a common receptacle, surrounded by an involucre composed of many bracts (Fig. 174), with usually 5 stamens inserted on the corolla, the anthers united into a tube which surrounds the style (Fig. 131). Calyx with its tube adnate to the ovary, the limb sometimes wanting, when present taking the form of scales, bristles, etc., known as *pappus* (Fig. 174). Corolla either strap-shaped or tubular (Fig. 110), in the former case often 5-toothed, in the latter usually 5-lobed. Style 2-cleft above. Fruit an akene, often provided with means of transportation (Figs. 174, 178, 179). The largest family of flowering plants

and among the most specialized for insect fertilization. The genera of the northern United States are divided into 2 sub-orders: I. TUBULIFLORÆ, corolla of the perfect flowers tubular and 5-lobed; II. LIGULIFLORÆ, corollas all strap-shaped and flowers all perfect.

I. TUBULIFLORÆ.

I. ERIGERON, FLEABANE.

Heads many-flowered, flat or nearly hemispherical, very many-rayed, the rays narrow, pistillate. Scales of the involucre narrow and overlapping but little. Akenes flattish, crowned with a single row of hair-like bristles (Fig. 110), or sometimes with shorter bristles or scales outside these. Disk yellow, rays white, pinkish, or purple.

a. (E. ANNUUS), COMMON FLEABANE. Stem grooved and stout, branching, 2–5 ft. high, with scattered hairs, lowest leaves petioled, ovate, coarsely toothed, those higher up the stem successively narrower, sessile; heads in a large loose corymb; rays short, white or purplish. Annual or biennial.

b. (E. STRIGOSUS), DAISY FLEABANE. Considerably resembling the preceding species, but with entire leaves, smaller and less branched stem, smaller heads, and longer rays. Annual or biennial.

c. (E. BELLIDIFOLIUS), ROBIN'S PLANTAIN. Soft-hairy; stems sometimes throwing out offsets from the base; simple, erect, 1–2 ft. high; root-leaves obovate-obtuse, somewhat serrate; stem-leaves few, lance-oblong, acute, clasping; heads rather large, 1–9, on long peduncles, with 50–60 long, rather broad, bluish-purple or reddish-purple rays. Perennial.

d. (E. PHILADELPHICUS.) Rather hairy; stems slender, about 2 ft. high; root-leaves spatulate and toothed; stem-leaves usually entire and strongly clasping, sometimes with a heart-shaped or eared base; heads several, small, long-petioled; rays exceedingly numerous, thread-like, reddish purple or flesh-color. Perennial.

II. ANTHEMIS, CHAMOMILE, MAYWEED.

Heads many-flowered, with ray-flowers, rays pistillate or neutral. Involucre of many small, dry, close-pressed scales. Akenes nearly cylindrical, generally ribbed; barely crowned

or naked at the summit. Aromatic or ill-scented herbs, with the leaves finely pinnately divided.

(A. COTULA), MAYWEED, DOG-FENNEL. Heads small, produced all summer, with yellow disk and rather short white neutral rays; leaves irregularly cut into very many narrow segments. A low, offensive-smelling annual weed, by roadsides and in barnyards.

III. CHRYSANTHEMUM, CHRYSANTHEMUM, OX-EYE DAISY.

Heads nearly as in the preceding genus, except that the ray-flowers are pistillate. Perennials with toothed pinnately cut or divided leaves.

a. (C. LEUCANTHEMUM), OX-EYE DAISY, WHITEWEED, BULL'S-EYE, SHERIFF PINK. Stem erect, unbranched or nearly so, 1–2 ft. high; root-leaves oblong-spatulate, petioled, deeply and irregularly toothed; stem-leaves sessile and clasping, toothed and cut, the uppermost ones shading off into bracts. Heads terminal and solitary, large and showy, with a yellow disk and many white rays. A troublesome but handsome perennial weed.

b. (C. FRUTESCENS), MARGUERITE. Erect, branching, woody below, smooth and with a pale bloom; divisions of the leaves linear, with the uppermost leaves often merely 3-cleft bracts; heads long-peduncled, showy, with a yellow disk and large, spreading white rays. Perennial, cultivated in greenhouses, from the Canary Islands.

IV. SENECIO, GROUNDSEL.

Heads many-flowered; ray-flowers pistillate or wanting; involucre usually of a single row of equal, erect scales. Receptacle flat and destitute of scales or chaff. Akenes tufted with abundant, soft, hair-like bristles. Flowers in most cases yellow.

(S. AUREUS), GOLDEN RAGWORT, SQUAW-WEED, SNAKE-ROOT. Sometimes covered with cottony wool when young, sometimes smooth, 1–3 ft. high; root-leaves varying greatly in shape in different varieties, long-petioled; lower stem-leaves obovate, with deep and narrow lobes toward the base; upper stem-leaves lanceolate, pinnately cut, sessile or with a somewhat clasping base; heads rather small, with 8–12 rays, in an umbel-shaped corymb. Many well-defined varieties are known. Perennial.

II. LIGULIFLORÆ.

TARAXACUM, DANDELION.

Head many-flowered, large, solitary, yellow, borne on a hollow scape which is short at first but lengthens after flowering. Involucre composed of a single row of long, erect, inner scales and a set of much shorter ones outside and at the base of the former ones. Akenes cylindrical or spindle-shaped, with 4–5 rough ribs, the apex tapering into a bristle-like beak which bears a short, broadly conical tuft of soft white hairs. Stemless perennial or biennial herbs, with a flattish tuft of pinnately cut or jagged leaves with the teeth bent backwards (Fig. 29).

(T. OFFICINALE), DANDELION. Outer involucre reflexed; inner involucre closing over the head, after the flowers are withered, and remaining shut for some days, then opening and allowing the tufted akenes to form a globular head. Root stout, bitter, medicinal. Young leaves eaten boiled, in spring, — the plant often cultivated for the leaves by market-gardeners.

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